FINAL REPORT

DEVELOPMENT OF IRRIGATION GUIDELINES TO ENHANCE SASKATOON AND CHOKECHERRY PRODUCTION AND FRUIT QUALITY

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Development Of Irrigation & Fertilization Guidelines To Enhance Saskatoon And Chokecherry Production And Fruit Quality

Project # 96000364

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A) Summary

The objectives of this project were: a) to track seasonal changes in leaf tissue and soil nutrient levels in saskatoons and chokecherries at a number of orchard locations, to relate changes in nutrient levels to plant response as measured by growth, yield and fruit quality, and to develop guidelines for the fertilization of saskatoons and chokecherries based on this information; and b) to determine how the timing and quantity of irrigation affect growth, yield and fruit quality of saskatoons and chokecherries, and to define guidelines for the irrigation of these crops, based on this information. In large part, the objectives of this study were met, although this required substantial additional work not included in the original proposal and which was subsidized by funding from other sources. Project achievements and outputs have included: a) 5 publications, 8 reports, and 5 presentations; b) general guidelines for the irrigation of saskatoons and chokecherries using soil moisture sensors; c) the determination of typical leaf nutrient concentrations in saskatoons and chokecherries; d) general guidelines for the fertilization of saskatoons and chokecherries; and e) a statement of interest in the results of this project from members of the Saskatchewan Fruit Growers Association, and an expression of desire to see more work done in this area.

The fertilization component of this project involved the analysis of soil and leaf tissue samples along with a number of greenhouse and field experiments. To develop standards for foliar nutrient levels in saskatoons and chokecherries, leaf samples were collected from saskatoons in 15 orchards, and from chokecherries in 3 sites. Typical leaf levels for the saskatoon in the month of August were nitrogen - 2.3 to 2.6%, phosphorus - 0.13 to 0.19% and potassium - 0.71 to 1.1%. Typical leaf levels for the chokecherry were nitrogen - 2.3 to 3%, phosphorus - 0.14 to 0.26% and potassium - 0.58 to 1.5%. A relationship between leaf and soil nutrients was not found in the field. This was likely due to the large variability in the data. This has been the most comprehensive study to date on the foliar analysis of saskatoons and chokecherries. Foliar analysis is particularly useful in determining the nutrient status of deep-rooted crops where soil sampling to the depth of tree roots can be difficult. Foliar nutrient standards allows growers to monitor leaf nutrient levels in their orchard and to fertilize accordingly to maintain these levels at typical concentrations.

Additional greenhouse pot and field experiments were initiated in order to derive additional information on plant response to the addition of varying levels of nitrogen. The field nitrogen fertilization project permitted the examination of leaf and soil nutrients under less variable conditions involving only one cultivar and one site. In this study, a relationship among soil and leaf nitrogen and shoot growth was found. The fertilization experiments of potted saskatoon plants grown in the greenhouse were valuable in establishing relationships between soil nutrient content, plant nutrient uptake, leaf nitrogen content, and plant growth response. The greenhouse research permitted nutrient uptake by the plant to be monitored. Based on these studies, the average amount of nitrogen taken up by the saskatoon plants to ensure an adequate leaf nitrogen content (mean = 2.4%) was 5.5 mg N/g plant dry weight. The relationship between

nitrogen uptake by the plant and its leaf nitrogen content was quite strong with an average correlation coefficient of 0.89; in other words, 89% of the plant's leaf nitrogen content was dependent on the amount of nitrogen taken up by the plant. From the results of the greenhouse experiments, one can estimate that the average one-year old saskatoon plant in the field would require approximately 100 mg of nitrogen from the soil. However, obviously more than this amount nitrogen fertilizer needs to be added to the plant root zone as the plant's roots will not be able to take up all of the nitrogen from the soil but only what its roots come in contact with.

On the basis of the work done in the fertilizer study, it appears that 25 to 45 lbs/acre of nitrogen could be applied to saskatoon orchards annually. However, the preferred method of adding fertilizer should be a proportional application based on soil nutrient loss and decrease in leaf tissue levels, provided that minimal initial levels of soil nutrients were in place when an orchard was established. Although typical leaf nutrient concentrations were determined in this study, additional research would be useful in order to refine this data in terms of nutrient deficiencies and toxicities. A larger scale study could also examine foliar nutrient content of plants of different cultivars or grown in the various soil zones. The quantity of fertilizer that needs to be applied in the field can only be determined through a number of seasons of field fertilization research. Fertilization research of plants grown in large pots to allow a natural root spread may also be beneficial. More research needs to be done on the effect of nitrogen fertilization on flowering of saskatoons and chokecherries. Some of the results of the soil and foliar analysis project were presented to growers at a Saskatchewan Fruit Growers workshop on February 25, 2000. Great interest was shown on the part of the growers in the use of foliar analysis to monitor the nutrient status and to determine the fertilization requirements of saskatoons and chokecherries. The growers felt that the results of this project were a good start, but expressed interest in seeing more research being done in this area.

For the irrigation component of this project, experimental orchards were established at Outlook (Saskatchewan Irrigation Diversification Centre) and Indian Head (PFRA Tree Nursery). Each site was approximately 0.8 hectare in area and was surrounded by a multiple row shelterbelt consisting of buffaloberry, sea buckthorn and chokecherry seedlings. Saskatoons and chokecherries were planted as separate trials. A randomized complete block experimental design with 6 replicates of six soil moisture treatments (irrigation at 15, 30, 45, 60, 75 and 90 centibars) was used. Data collection from the field trials included rainfall, soil water tension, mean annual shoot growth, mean sucker production, and, when fruit were produced, mean bush yield and mean fruit weight. In addition, two thirteen week greenhouse trials were conducted during the 1998 season to monitor the response of young saskatoon plants to varying soil moisture levels. One year old Smoky saskatoon plants were planted in pots, and treatments consisting of four irrigation application points (20, 40, 60 and 80 centibars) were arranged in a randomized complete block design (RCBD) with 3 plants per treatment and 5 replicates. Data collected from these trials included weekly monitoring of shoot growth and final above and below ground fresh and dry weights.

Large amounts of precipitation received during the 1998 and 1999 seasons meant that it

was not possible to determine the impact of irrigation on yield and growth in established saskatoon and chokecherry orchards. However, from the results of the additional greenhouse trials, and through observations made during the trial period, a number of general conclusions could be made. Soil moisture during May and early-June rarely required irrigation treatments to be applied. In the absence of rainfall, most soil moisture loss occurred during periods of rapid growth and fruit development, that is, during the months of June and July. In treatments of the field study of saskatoon and chokecherry, where soil moisture was depleted to levels above 60 centibars, it was noted that repeated irrigation applications were required to completely replenish soil moisture. This suggests that a typical trickle irrigation system may not be able to immediately supply adequate moisture if the soil is allowed to dry out excessively before the system is turned on. This is not surprising considering trickle irrigation systems are only designed to replenish soil moisture lost during a single day. This would also suggest that there may be risks associated with delaying irrigation applications if a grower is using a trickle irrigation system. Soil moisture levels which were maintained between 20 and 40 centibars produced the greatest amount of plant growth in saskatoon plants grown in the greenhouse. During these trials, soil moisture levels were monitored daily and were not allowed to stray far from the target treatment levels. Growers should be mindful of the importance of checking soil moisture levels daily in order consistently maintain the target soil moisture range. When using soil moisture sensors with recently transplanted saskatoons, it was found that placement of the sensing unit next to the base of the transplant's root plug would not accurately reflect water loss occurring inside the root plug. It was determined that the root plug of young saskatoon transplants dehydrate at the rate of soil near the top of the root plug even if soil near the base of the plug is adequately moist. To prevent root damage from dehydration in newly transplanted saskatoons, the moisture level of the soil near the top of the root plug must be monitored in order to determine irrigation requirements.

Based on the information gathered in this study, it is recommended that growers use soil moisture sensors in their orchards, and that soil moisture levels be maintained at the 20 to 40 centibar level at 5 to 30 cm soil depth, depending on plant size. New transplants should be monitored closely and irrigated every 1 to 2 days so as to ensure that the root plug does not dry out.

B) Technical Report

1) Background & Objectives

The objectives of this project were: to determine how the timing and quantity of irrigation affect growth, yield and fruit quality of saskatoons and chokecherries; to define guidelines for the irrigation of these crops; to track seasonal changes in leaf tissue and soil nutrient levels in saskatoons and chokecherries at a number of orchard locations; to relate changes in nutrient levels to plant response as measured by growth, yield and fruit quality; and to develop guidelines for the fertilization of saskatoons and chokecherries.

Scientifically established guidelines for irrigation and fertilization and knowledge of the effects of irrigation and fertilization on the response of saskatoons and chokecherries are not available. This project will help address the needs of the fruit industry for improved management technology for native fruit crops, and will help the developing native fruit industry, thus enhancing diversification of Saskatchewan's agri-food industry, and encouraging Saskatchewan farmers and rural residents to create economic opportunities and jobs.

The widespread cultivation of fruit species in orchards and shelterbelts could significantly contribute to the diversification and health of the prairie agricultural economy by enhancing alternative agricultural production, by promoting the development of mixed farming operations, by providing a more substantive base for a processing industry, by promoting the growth of the fruit processing industry, and ultimately, by providing increased, diversified employment and income for the family farm.

Available market studies suggest that demand for native fruits exceeds supply. Current demand for saskatoons has been estimated at 5 to 6 million pounds annually; it is anticipated that this demand will increase to 12 to 15 million pounds annually over the next few years. The growing trend towards fruit processing will likely drive any major expansion of fruit production in Saskatchewan. A recent study (SIAP's Specialty Berry Market Assessment Study - October 1994) suggests good market opportunities for fruit beverages (from juice concentrates), teas, dried fruit products, and fresh fruit. Processors primarily use cultivated fruit; wild fruit are not consistent in terms of quality (color, flavor, size, damage from insects and disease). Consistent quality can only be provided by growing properly evaluated cultivars in well-managed orchards.

Progress in the further development of the fruit industry in Saskatchewan is impeded by a number of factors including inconsistent yields, ill-defined management practices, and a lack of information concerning the production and processing potential of most native fruit cultivars, fresh product storage and handling practices, fruit quality characteristics, and how fruit quality is affected by management practices. Improved field management practices are necessary in order to stabilize yields and therefore to provide a consistent supply of fruit, and to reduce the cost of orchard management.

Irrigation & Water Use

Generally, irrigation is required for commercial fruit production in Saskatchewan. The Province receives an average of 25-35 cm water annually, about half of which is considered available to the crop. Water requirements of fruit crops generally are in excess of water available from precipitation.

Plant growth, yield and fruit quality are sensitive to water stress. Irrigation is used to increase the total amount of available water, or to adjust the distribution of water to better fit crop requirements. The primary goal of orchard water management is to provide adequate supplies of water to fruit plants with a reasonable investment of time, money and other resources, without creating salinity or waterlogging problems, and without jeopardizing the quality or quantity of water for future use. The efficient use of water means using the smallest amount of water to produce the largest harvest in ways that do not cause these problems.

Most native fruit species, like the saskatoon and chokecherry, will survive under normal moisture conditions without supplemental irrigation, provided that weeds are not allowed to grow. However, irrigation will improve orchard establishment and rapid growth, appears essential for production at an earlier age, and may be required to maximize fruit yield, depending on natural rainfall. The successful establishment of fruit crops will very largely depend on the supply of water to the young plants during their first two dry seasons. In general, adequate soil moisture is required to maximize growth and yield of fruit crops. Adequate moisture is essential during the critical stages of leaf expansion, bloom, fruit set and fruit enlargement. The critical periods for shoot growth, fruit growth and bud development for the following year occur from about mid-May through late-July. When available soil water is reduced, young plants with limited root systems show reduced growth more quickly than do older plants having deeper more extensive root systems. A large, bearing surface and greater yields are the cumulative result of the previous 2 to 5 years of shoot growth and leaf production. Frequent irrigation and no cultivation encourage roots to grow near the soil surface which is usually more mineral rich. There is a consequent increase in fruit size but too frequent irrigation can decrease flavour and long term keeping quality.

Applying appropriate amounts of water at the right time is important to reducing costs and maximizing profits. Excess water as a result of over-irrigating reduces yields, contributes to increased disease problems, can result in root damage and rot from poor soil aeration, may prevent the uptake of mineral nutrients and water, delays maturity and increases winter damage. Excessive water contributes to insipid fruit flavour and fruit cracking. Proper irrigation is essential for nutrient utilization; excessive irrigation can damage soil structure, will leach nutrients below root systems and may contribute to pollution of ground water sources. Irrigation may also leach herbicides below the zone of germinating weed seeds. Ultimately, over-irrigating wastes a grower's time and money.

No scientific studies on the effects of timing and quantity of irrigation on growth, yield

and fruit quality of native fruit species have been published. Current recommendations for irrigation are, at best, educated guesses. Data obtained from this study will allow substantially better recommendations for irrigation of native fruit species to be made.

Fertilization

Fertilization is an inexact science for fruit crops such as the saskatoon whose nutrient requirements are unknown. It is certain however, that fruit production utilizes soil nutrients and that these must eventually be replaced. Proper use of fertilizers is important to reducing costs, to growing healthy plants, and to minimizing the ecological impact of fertilizers on water bodies. An excess of fertilizer can result in problems as serious as a deficiency. Over-fertilization can be detrimental to the plant and is an unnecessary expense.

A wide variety of fertilization practices have been suggested for saskatoons in the past, however, it is not known how saskatoons respond to such practices. Knowledge of fertilization practices for chokecherries is completely lacking. In light of the lack of knowledge regarding specific fertilization practices for saskatoons and chokecherries, how should a grower look after the nutritional requirements of these fruit crops? There is no simple solution. The determination of specific nutrient requirements is complex and inaccurate to a certain extent because of variable responses by the fruit crop. Plant growth and yield is associated with the concentration of mineral nutrients available, but especially the ratio among these nutrients. Fertilizer requirements are best determined through annual monitoring of soil and leaf tissue analyses for several years, in relationship to records of shoot growth, yield, fruit quality, pest problems and weather.

Soil tests estimate nutrient availability, pH and salinity. Leaf tests reflect the nutritional status of the plant. What a plant can obtain from the soil is more important than the concentrations of nutrients found in the soil. Foliar analysis, or leaf tissue testing, provides an index of a plant's nutritional status. Foliar analysis is the most accurate method of determining which nutrient or nutrients are limiting to the fruit crop, provided that optimum nutrient concentrations are known, and if normal, deficient and excessive concentrations have been established. Foliar analysis also is used to diagnose nutrient disorders and to prescribe remedial action.

No scientific studies on the effects of timing, quantity or type of fertilization on growth, yield and fruit quality of these native fruit species have been published.

Results from this project will be of direct benefit to Saskatchewan's agri-food industry. The information derived from the proposed project could enhance both grower and processor profits. Improved irrigation and fertilization practices will help reduce orchard management costs. This project has the potential to contribute to the fruit industry's knowledge and skill at production and processing by helping to increase the quality of fresh and processed fruit products produced, therefore improving the ability of both growers and processors to compete in the

available markets. This project will help the developing native fruit industry, thus enhancing diversification of Saskatchewan's agri-food industry, and encouraging Saskatchewan farmers and rural residents to create economic opportunities and jobs. The project is integrated with the Saskatchewan Fruit Growers Association's Strategic Plan. It is anticipated that commercial application of the results of this project will begin to occur within a year of project completion.

2) Activities & Achievements

a) Activities

Irrigation & Water Use

Experimental orchards were previously established at Outlook (Saskatchewan Irrigation Diversification Centre) and Indian Head (PFRA Tree Nursery). Each site was approximately 0.8 hectare (2 acres) in area and was surrounded by a multiple row shelterbelt consisting of buffaloberry, sea buckthorn and chokecherry seedlings.

Saskatoons and chokecherries were planted as separate trials. Initially, a split-plot experimental design was used with amount of water being the main factor, and timing the secondary factor. Amount of water was defined in terms of soil water tension. Irrigation was to be applied when soil water tension dropped to 40 centibars for the first group of treatments, and when soil water tension dropped to 60 centibars for the second group of treatments. Within these two primary groups of treatments, six treatments are defined as follows: a) consistent irrigation; b) no irrigation; c) no irrigation June 1 to 30; d) no irrigation June 15 to July 15; e) no irrigation July 1 to 31; and f) no irrigation from July 15 on (Table 1).

Table 1. Summary of soil moisture and irrigation timing treatment combinations used during the 1997 season.

Soil Moisture (cbars)	Consistent irrigation	No irrigation June 1- June 30	No irrigation June 15 - July 15	No irrigation July 1 - July 31	No irrigation after July 15	No irrigation all season
40	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6
60	Treatment 7	Treatment 8	Treatment 9	Treatment 10	Treatment 11	Treatment 12

It was found that irrigation timing treatments were difficult to implement under field conditions due to limited soil moisture loss early in the season and the impact of unplanned rains. It was apparent from the data collected during the 1997 season that some changes should be made in order the simplify these trials and improve the chances of obtaining useful data.

Characterizing plant response to varying levels of soil moisture should provide information that can be directly related to grower irrigation practices.

A number of changes to experimental design were implemented during the 1998 season. For both trials at Outlook and the chokecherry trial at Indian Head, the number of treatments was reduced to 6 soil moisture levels and the irrigation timing component of the trial was eliminated. This allowed the number of replicates to be increased from 3 to 6. The experimental design was therefore changed to a randomized complete block design (RCBD) with 6 replicates and 6 soil moisture treatments (irrigation at 15, 30, 45, 60, 75 and 90 centibars). Due to the high mortality rate at one end of the saskatoon trial at Indian Head, the trial was limited to 4 treatments (irrigation at 20, 40, 60 and 80 centibars). A randomized complete block experimental design (RCBD) with 6 replicates was also used.

Data collection from the field irrigation trials included rainfall, soil water tension, mean annual shoot growth, mean sucker production, and, when fruit were produced, mean bush yield and mean fruit weight.

In addition to the field trials, two thirteen week greenhouse trials were conducted during the 1998 season to monitor the response of young saskatoon plants to varying soil moisture levels. The first greenhouse trial was started in January and the second began in May. One year old Smoky saskatoon plants were planted in pots containing field soil which was amended with turface and perlite to improve drainage. Treatments consisting of four irrigation application points (20, 40, 60 and 80 centibars) were arranged in a randomized complete block design (RCBD) with 3 plants per treatment and 5 replicates. Data collected from these trials included weekly monitoring of shoot growth and final above and below ground fresh and dry weights.

Fertilization

The soil and foliar analysis component of this project involved the analysis of soil and leaf tissue for nutrient content in order to develop nutrient standards for growing saskatoons. The soil and foliar analysis project was divided into two parts: a) a simplified study in which grower's participated; and b) a more comprehensive study conducted by the Native Fruit Development Program. To develop standards for foliar nutrient levels in chokecherries, leaf samples were collected from chokecherries at three sites in Saskatchewan.

A fertilization experiment of potted saskatoon plants was conducted in the greenhouse to study the response of saskatoons to various fertilizer rates. This experiment was repeated in January, 2000.

A nitrogen fertilizer greenhouse pot experiment was commenced in December, 1998. Plant Root Simulator (PRS™) probes were used to measure and monitor soil nutrients in the pots. Half of the plants were harvested in the spring of 1999 and the remainder were given a cold

period and then returned to the greenhouse in the fall to continue the study for another growing period.

A field nitrogen fertilization experiment was established in 1998 at a cooperative grower's site near White City. This site was selected for its light soil texture which is more inclined to have low soil nitrogen levels. It was hoped that this study would provide information on the effect of nitrogen fertilization on flowering and fruit set of saskatoons in a field situation. This study was continued in 1999.

An additional field nitrogen fertilization experiment was started in the spring of 1999 in an older orchard at the University of Saskatchewan research plots. This orchard had never been fertilized and thus, may show more response to nitrogen fertilization.

b) Achievements

In large part, the objectives of this study were met, although this required substantial additional work not included in the original proposal and which was subsidized by funding from other sources. Project achievements and outputs have included: a) 5 publications, 8 reports, and 5 presentations; b) general guidelines for the irrigation of saskatoons and chokecherries using soil moisture sensors; c) the determination of typical leaf nutrient concentrations in saskatoons and chokecherries; d) general guidelines for the fertilization of saskatoons and chokecherries; and e) a statement of interest in the results of this project from members of the Saskatchewan Fruit Growers Association, and an expression of desire to see more work done in this area.

3) Results, Discussion & Conclusions

Irrigation & Water Use

1997

At Outlook, precipitation was lower than average with only 138.8 mm occurring from the beginning of May until the end of August (Table 2). Soil moisture levels were stable during the early part of the season and dropped off slightly during July and August in most treatments (Figures 1 & 2) in spite of very low rainfall during these months. No irrigation treatments were applied in the chokecherry trials and very few treatments were required in the saskatoon trial, therefore no conclusions could be made from this season's data (Table 3). Simplification of the irrigation treatments should produce more meaningful information from these trials.

Figure 1. Summary of irrigation treatments applied at Outlook in the saskatoon trial, 1997.

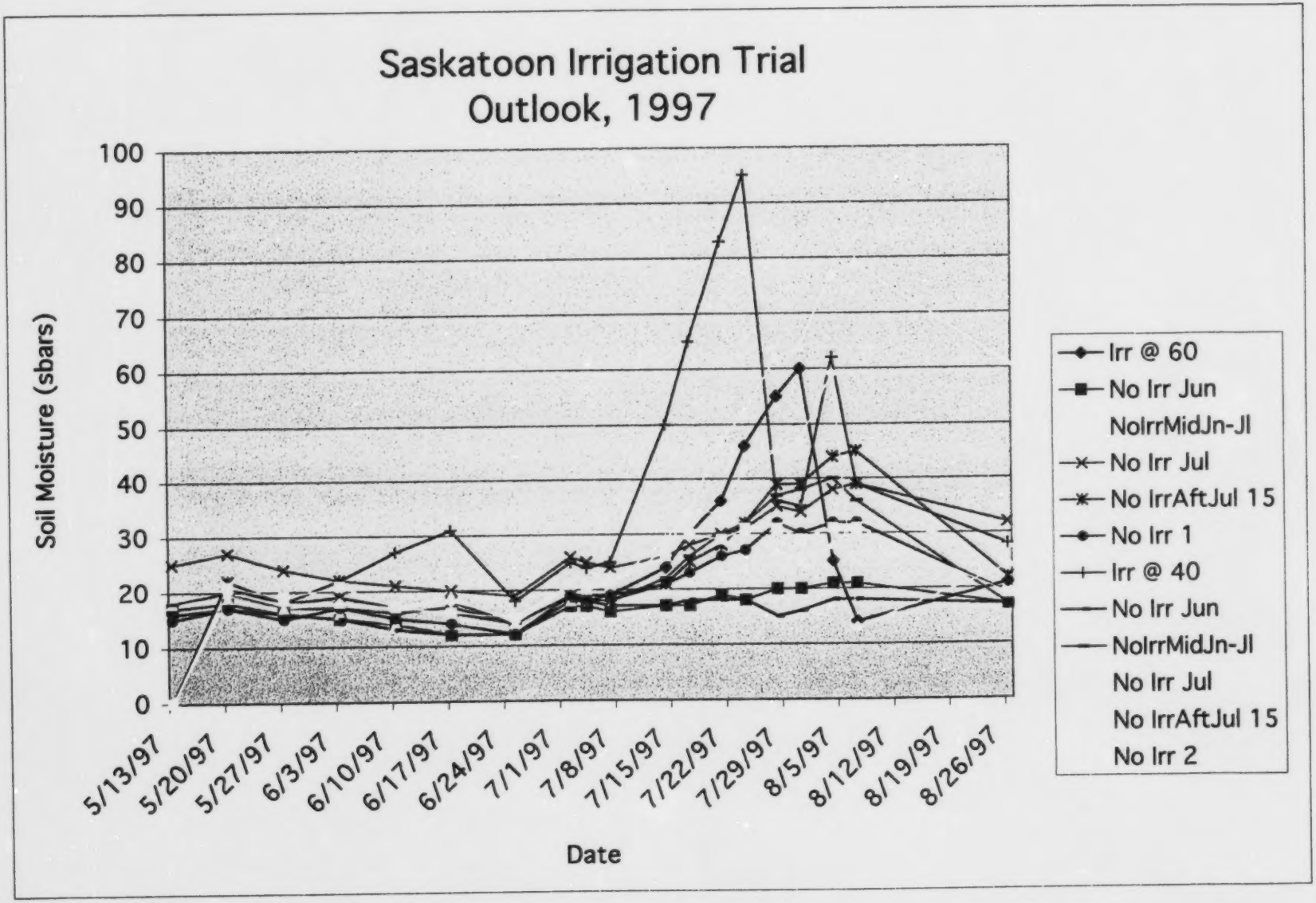


Figure 2. Summary of irrigation treatments applied at Outlook in the chokecherry trial, 1997.

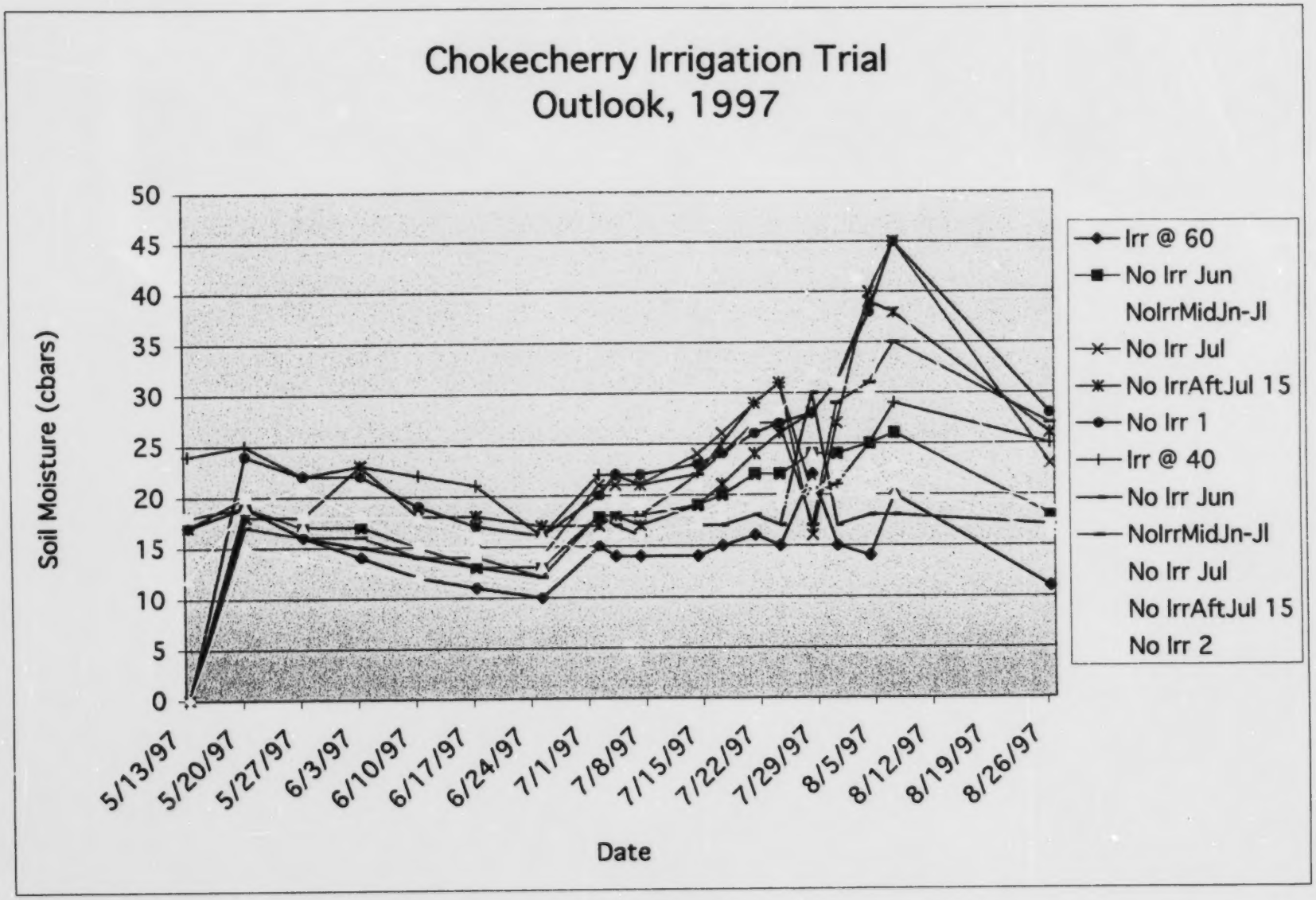


Table 2. Monthly precipitation (mm), Outlook and Indian Head (1997)					
Site	May	June	July	August	Total
Indian Head	36.0	29.6	46.4	46.7	158.7
Outlook	18.4	80.0	34.2	6.2	138.8

At Indian Head there was very little rain during the 1997 season and soil moisture dropped off sharply in July, as crop water use increased, and to a lesser degree in June and August (Figures 3 &4). Distinct differences in soil moisture levels were observed between many of the treatments, however this had no effect on caliper growth, suckering or survival in either crop tested (Table 4).

Table 3. Survival, growth and sucker production under varying irrigation treatments, Outlook, 1997.

Crop	Chokecherry			Saskatoon		
Treatment	Survival (%)	Mean Caliper Growth (mm)	Suckers Produced	Survival (%)	Mean Caliper Growth (mm)	Suckers Produced
2	100 +/- 0	3.7 +/- 0.5	0.3 +/- 0.5	100 +/- 0	4.7 +/- 1.3	1.0 +/-0.3
3	100 +/- 0	4.3 +/- 0.4	0.6 +/- 0.9	100 +/- 0	3.8 +/- 0.7	0.9 +/- 1.0
4	100 +/- 0	4.1 +/- 0.6	0.9 +/- 1.0	100 +/- 0	4.6 +/- 0.4	1.9 +/- 1.4
5	86.7 +/- 11.6	5.1 +/- 0.4	0.4 +/- 0.8	100 +/- 0	4.6+/- 0.3	1.0 +/- 0.6
6	100 +/- 0	4.7+/- 0.4	0.7 +/- 0.7	100 +/- 0	5.5 +/- 0.9	2.6 +/- 0.7
7	100 +/- 0	5.0 +/- 0.4	0.4 +/- 0.2	100 +/- 0	4.1 +/- 0.5	1.7 +/- 0.6
8	100 +/- 0	5.2 +/- 0.5	0.6 +/- 0.7	100 +/- 0	4.0 +/- 1.6	1.8 +/- 1.6
9	93.3 +/- 11.6	4.3 +/- 0.8	0.3 +/- 0.3	100 +/- 0	5.2 +/- 1.0	2.0 +/- 1.9
10	86.7 +/- 11.6	4.2 +/- 0.5	0.7 +/- 0.3	100 +/- 0	5.4 +/- 0.4	2.6 +/- 0.5
11	100 +/- 0	4.3 +/- 0.1	0.2 +/- 0.4	100 +/- 0	5.2 +/- 1.2	2.6 +/- 1.4

Figure 3. Summary of irrigation treatments applied at Indian Head in the saskatoon trial, 1997.

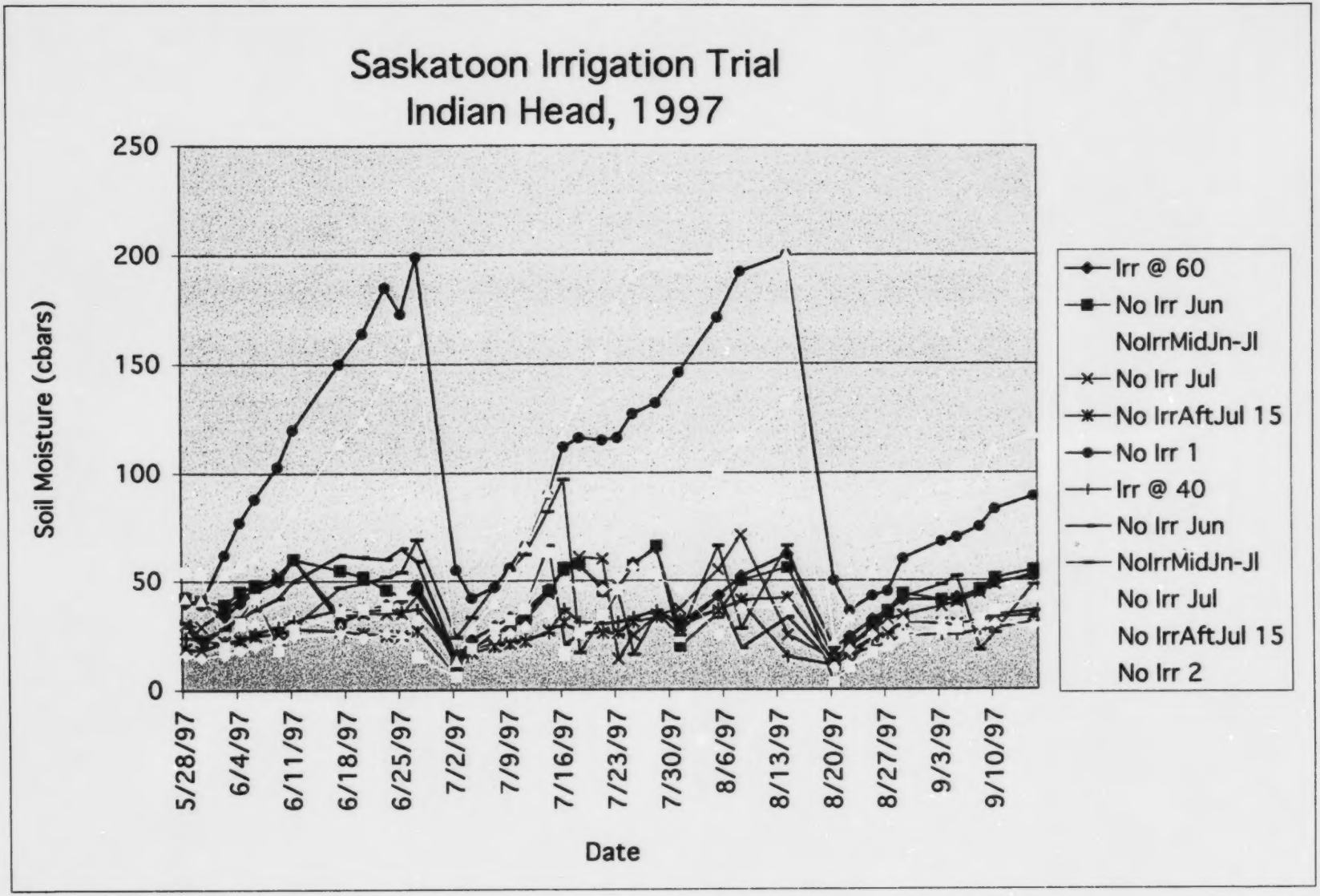
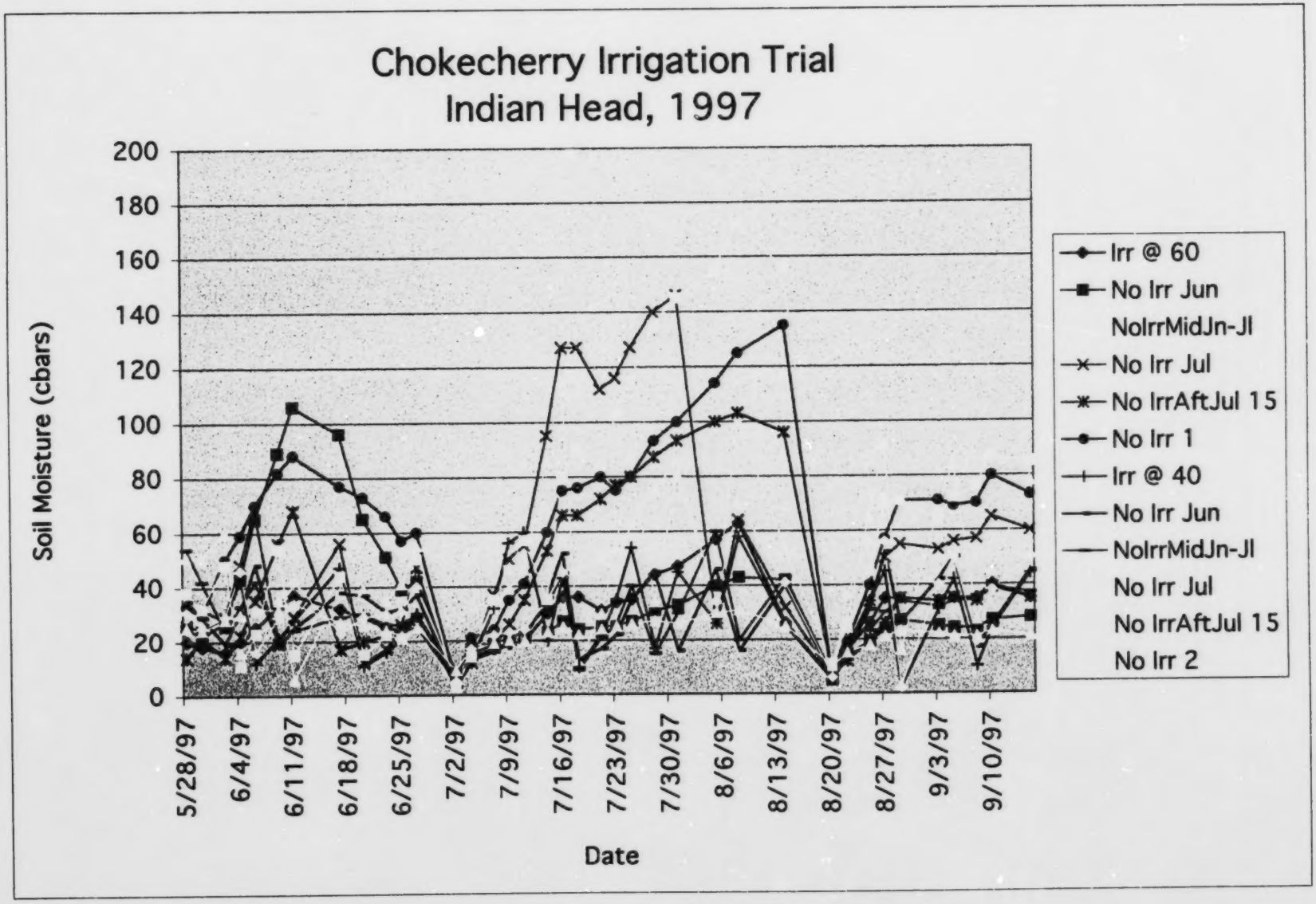


Figure 4. Summary of irrigation treatments applied at Indian Head in the chokecherry trial, 1997.



12	100 +/- 0	4.5 +/- 0.6	0.7 +/- 0.9	100 +/- 0	4.6 +/- 0.8	1.1 +/- 0.4
Mean of 3 replicates. +/- values are the standard deviation of the mean.						

Table 4. Survival, growth and sucker production under varying irrigation treatments, Indian Head, 1997.

Crop	Chokecherry			Saskatoon		
Treatment	Survival (%)	Mean Caliper Growth (mm)	Suckers Produced	Survival (%)	Mean Caliper Growth (mm)	Suckers Produced
2	100 +/- 0	1.4 +/- 0.7	0.9 +/- 0.5	66.7 +/- 23.1	1.8 +/- 1.7	1.8 +/- 1.7
3	100 +/- 0	3.0 +/- 0.8	0.6 +/- 0.4	66.7 +/- 11.6	2.9 +/- 1.7	1.8 +/- 0.4
4	100 +/- 0	1.9 +/- 0.5	0.5 +/- 0.4	53.3 +/- 50.3	3.6 +/- 0.5	3.5 +/- 2.5
5	100 +/- 0	3.0 +/- 1.9	0.8 +/- 0.7	86.7 +/- 11.6	4.2 +/- 0.2	2.8 +/- 1.6
6	100 +/- 0	1.8 +/- 1.3	0.9 +/- 0.7	66.7 +/- 11.6	2.3 +/- 0.7	1.9 +/- 0.8
7	100 +/- 0	1.2 +/- 0.7	0.8 +/- 0.8	53.3 +/- 30.6	3.5 +/- 2.2	1.8 +/- 1.6
8	100 +/- 0	1.3 +/- 0.9	1.1 +/- 1.0	73.3 +/- 11.6	1.8 +/- 1.5	3.1 +/- 3.7
9	100 +/- 0	1.3 +/- 0.9	1.3 +/- 1.2	73.3 +/- 23.1	1.8 +/- 1.2	2.0 +/- 1.7
10	100 +/- 0	2.7 +/- 1.4	0.6 +/- 0.7	60.0 +/- 0	2.3 +/- 1.0	1.1 +/- 0.8
11	100 +/- 0	2.4 +/- 1.6	1.6 +/- 0.8	60.0 +/- 0	1.8 +/- 1.1	1.4 +/- 1.4
12	100 +/- 0	1.5 +/- 1.1	0.8 +/- 0.4	70.0 +/- 17.3	3.0 +/- 0.7	3.6 +/- 0.7
Mean of 3 replicates. +/- values are the standard deviation of the mean.						

1998

The amount of precipitation was greater at both sites during the 1998 season with most of the precipitation falling during June and August at Outlook and during May and June at Indian Head (Table 5). The site at Indian Head received enough rainfall that few irrigation treatments were required in either trial. In the saskatoon irrigation trial at Outlook, the 15 centibar soil moisture level treatment was watered on a regular basis. This treatment required fewer irrigation applications in the chokecherry trial. Soil moisture levels were generally adequate during June,

July and August, but the rate of soil drying varied between treatments (Figures 5 to 8). Variability in soil texture and differences in placement of soil moisture sensors relative to the root zone may have contributed to these unexpected soil moisture readings. It was noted that once treatments became very dry repeated irrigation applications were required to significantly impact soil moisture. This suggests that a typical trickle irrigation system may not be able to supply adequate moisture if the soil is allowed to dry excessively before the system is turned on.

Table 5. Monthly precipitation (mm), Outlook and Indian Head (1998).

Site	May	June	July	August	Total
Indian Head	84.2	160.5	36.3	29.8	310.8
Outlook	10.0	100.3	16.7	68.6	195.6

None of the treatements had any effect of shoot growth or sucker production (Table 6). No fruit were produced in the chokecherry trials at either site or in the saskatoon trial at Indian Head. The saskatoon trial at Outlook did produce very modest yields but this fruit was severely damaged by hail.

Table 6. Shoot growth and sucker production in chokecherry and saskatoon irrigation trials (1998)

Site	Treatment (cbars)	Chokecherry		Saskatoon	
		Shoot Growth (cm)	Sucker #	Shoot Growth (cm)	Sucker #
Outlook	15	40.6 +/- 3.0	3.4 +/- 1.6	34.8 +/- 5.8	5.6 +/- 0.9
	30	33.9 +/- 3.9	3.2 +/- 1.7	33.9 +/- 4.9	7.0 +/- 4.5
	45	39.2 +/- 3.8	2.5 +/- 1.2	32.4 +/- 4.1	8.8 +/- 4.0
	60	28.2 +/- 4.7	2.9 +/- 1.5	33.3 +/- 6.4	6.2 +/- 1.1
	75	36.8 +/- 4.7	2.8 +/- 0.9	34.9 +/- 3.9	5.4 +/- 2.8
	90	36.4 +/- 4.1	2.8 +/- 1.7	33.6 +/- 3.8	5.8 +/- 2.9
Indian Head	15	64.4 +/- 5.5	0.7 +/- 0.7		

Figure 5. Summary of irrigation treatments applied at Outlook in the saskatoon trial, 1998.

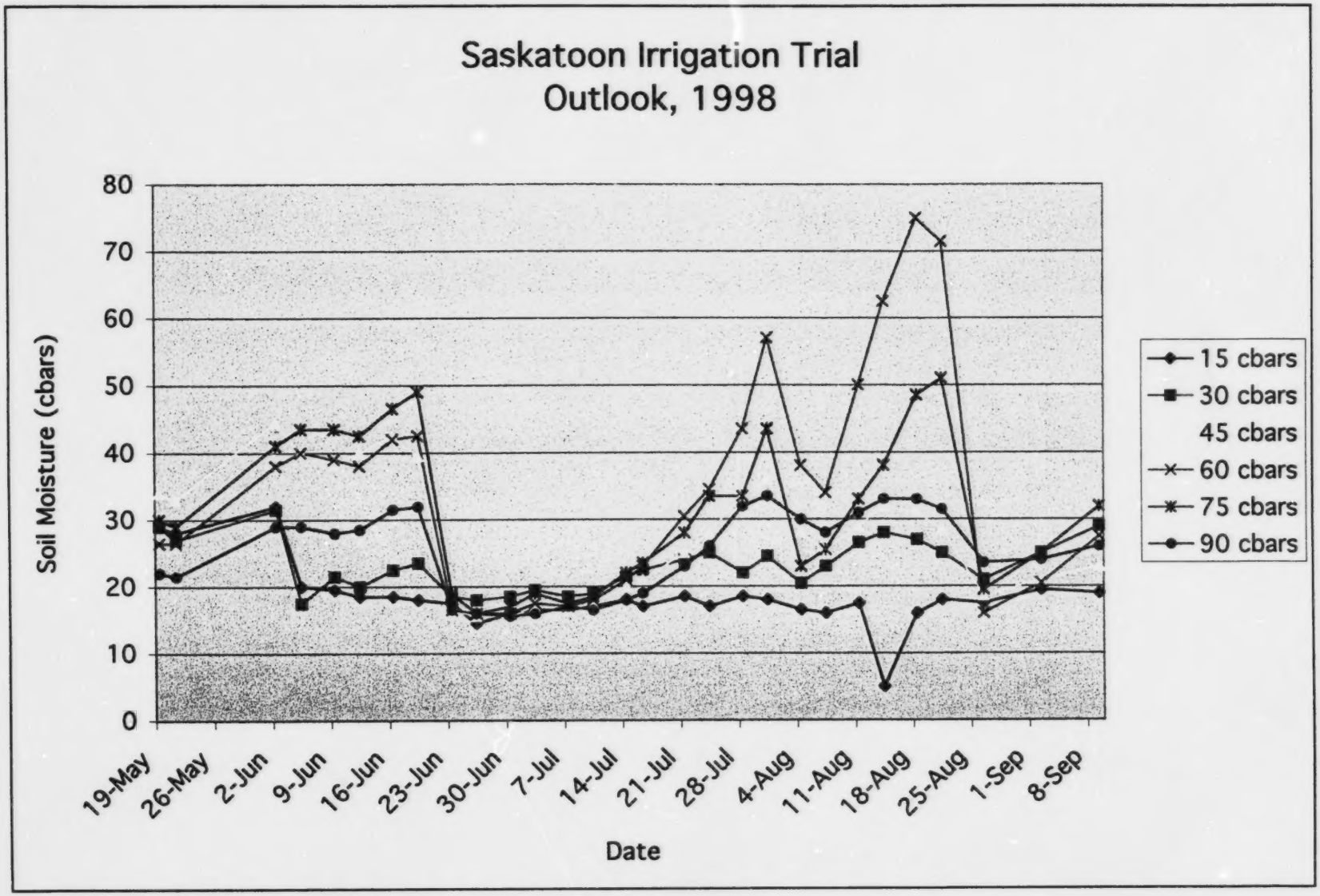


Figure 6, Summary of irrigation treatments applied at Outlook in the chokecherry irrigation trial, 1998.

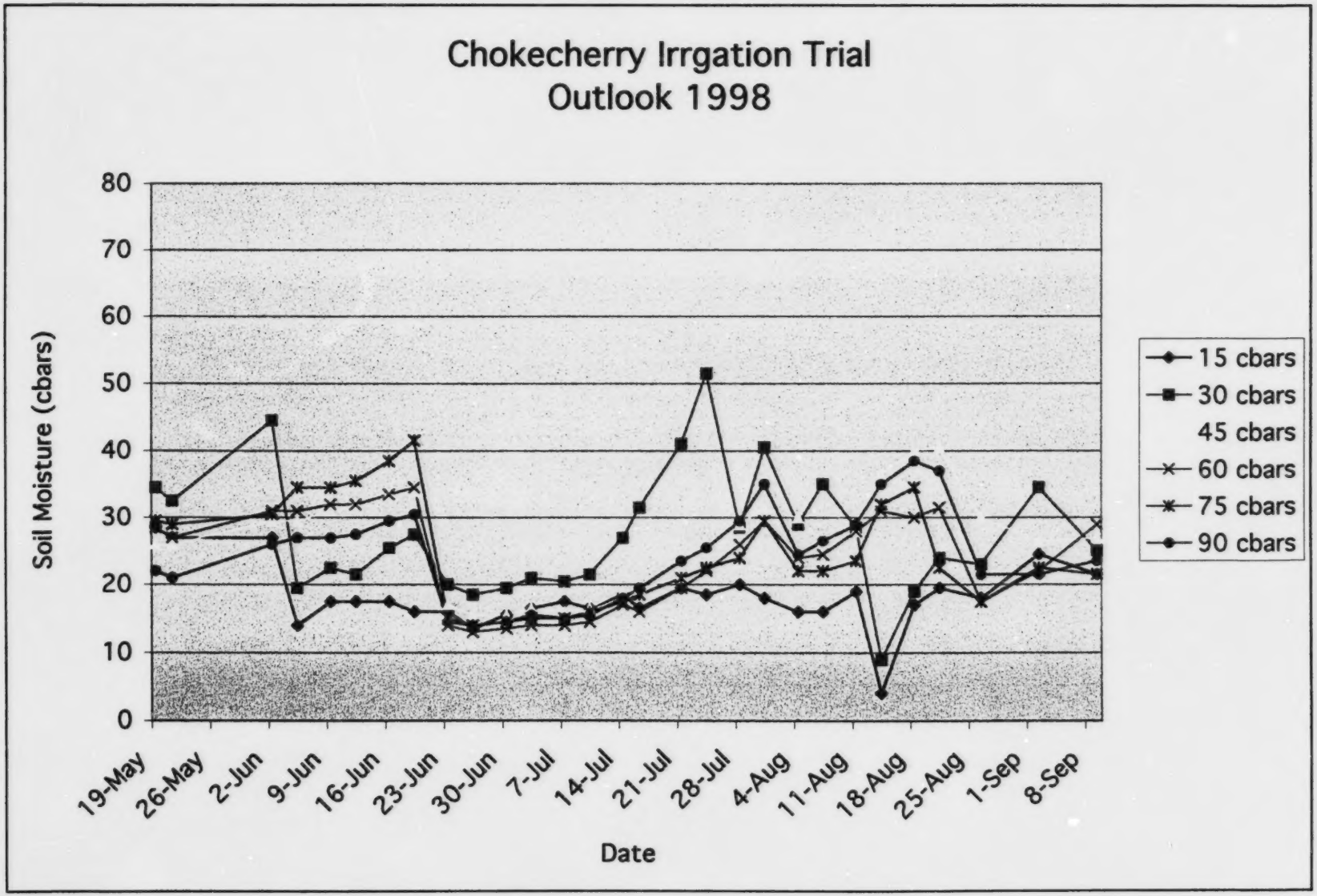


Figure 7. Summary of irrigation treatments applied at Indian Head in the saskatoon trial, 1998.

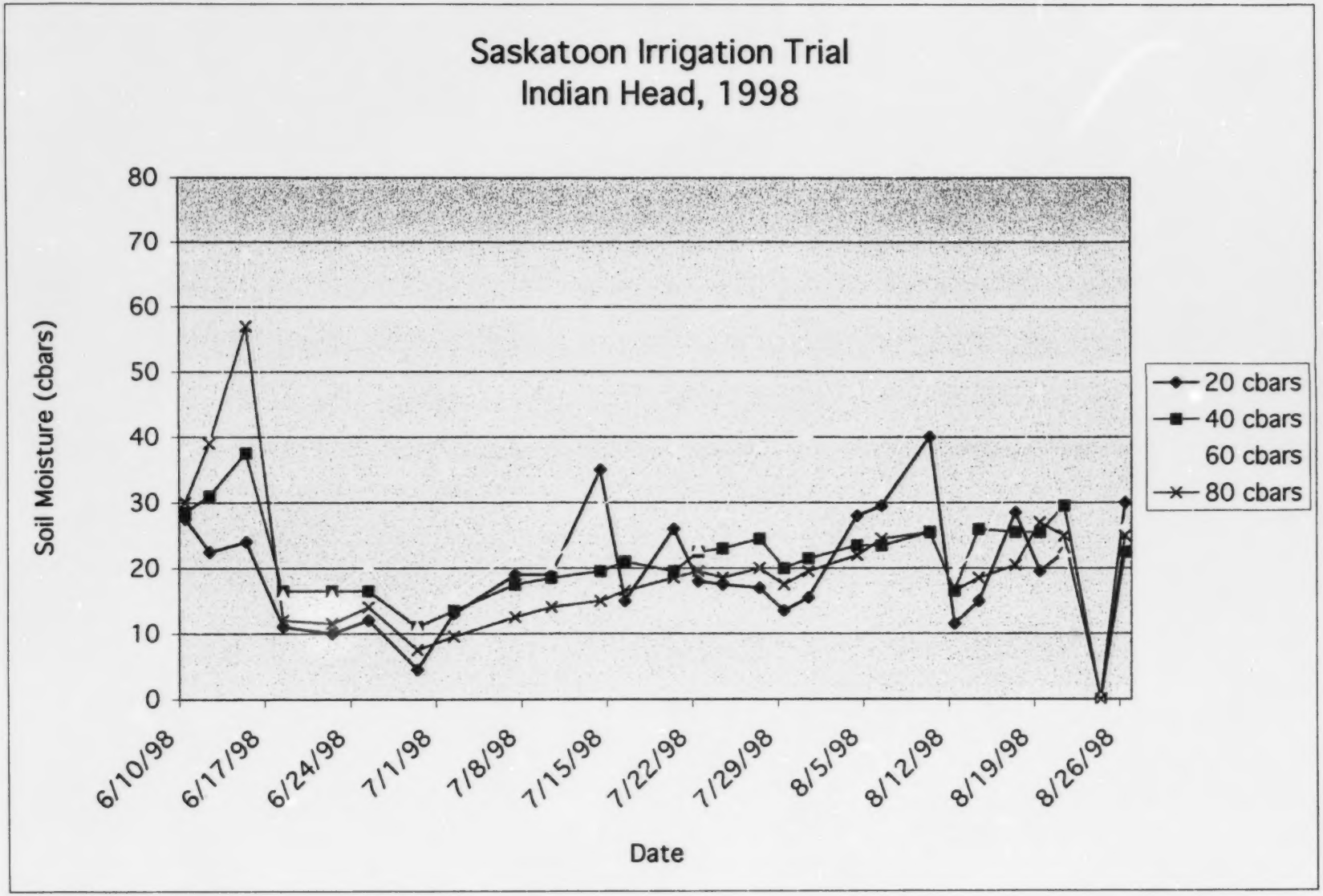
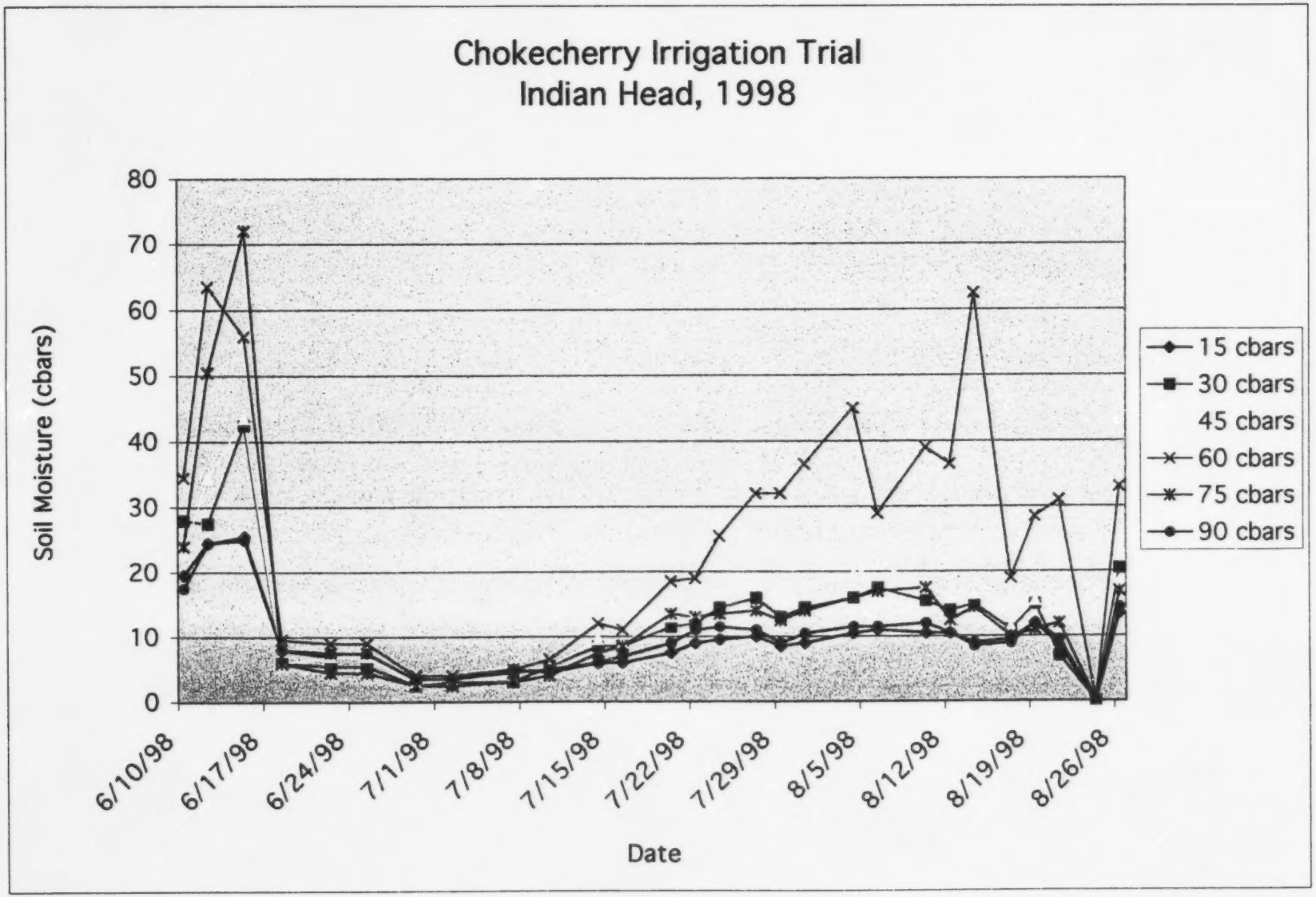


Figure 8. Summary of irrigation treatments applied at Indian Head in the chokecherry trial, 1998.



	30	63.6 +/- 3.8	1.3 +/- 0.8		
	45	61.1 +/- 5.6	1.5 +/- 0.9		
	60	66.4 +/- 0.6	0.6 +/- 0.5		
	75	63.9 +/- 4.6	1.4 +/- 0.9		
	90	62.6 +/- 6.4	1.0 +/- 0.8		
	20			45.2 +/- 6.6	6.3 +/- 2.0
	40			44.0 +/- 7.8	5.9 +/- 2.4
	60			39.5 +/- 6.8	4.8 +/- 1.3
	80			37.4 +/- 9.2	4.9 +/- 3.2
Mean of six replicates. +/- values are the standard deviation of the mean.					

1999

The amount of precipitation occuring during the 1999 season was very high at both sites (Table 7) and very few irrigation treatments were required at either site (figures 9 and 12).

Table 7. Monthly precipitation (mm), Outlook and Indian Head (1999)					
Site	May	June	July	August	Total
Indian Head	86.4	115.6	83.6	86.4	372.0
Outlook	61.4	63.2	91.2	37.8	253.6

A summary of the treatment results are presented in Tables 8 and 9.

Figure 9. Summary of irrigation treatments applied at Outlook in the saskatoon irrigation trial, 1999.

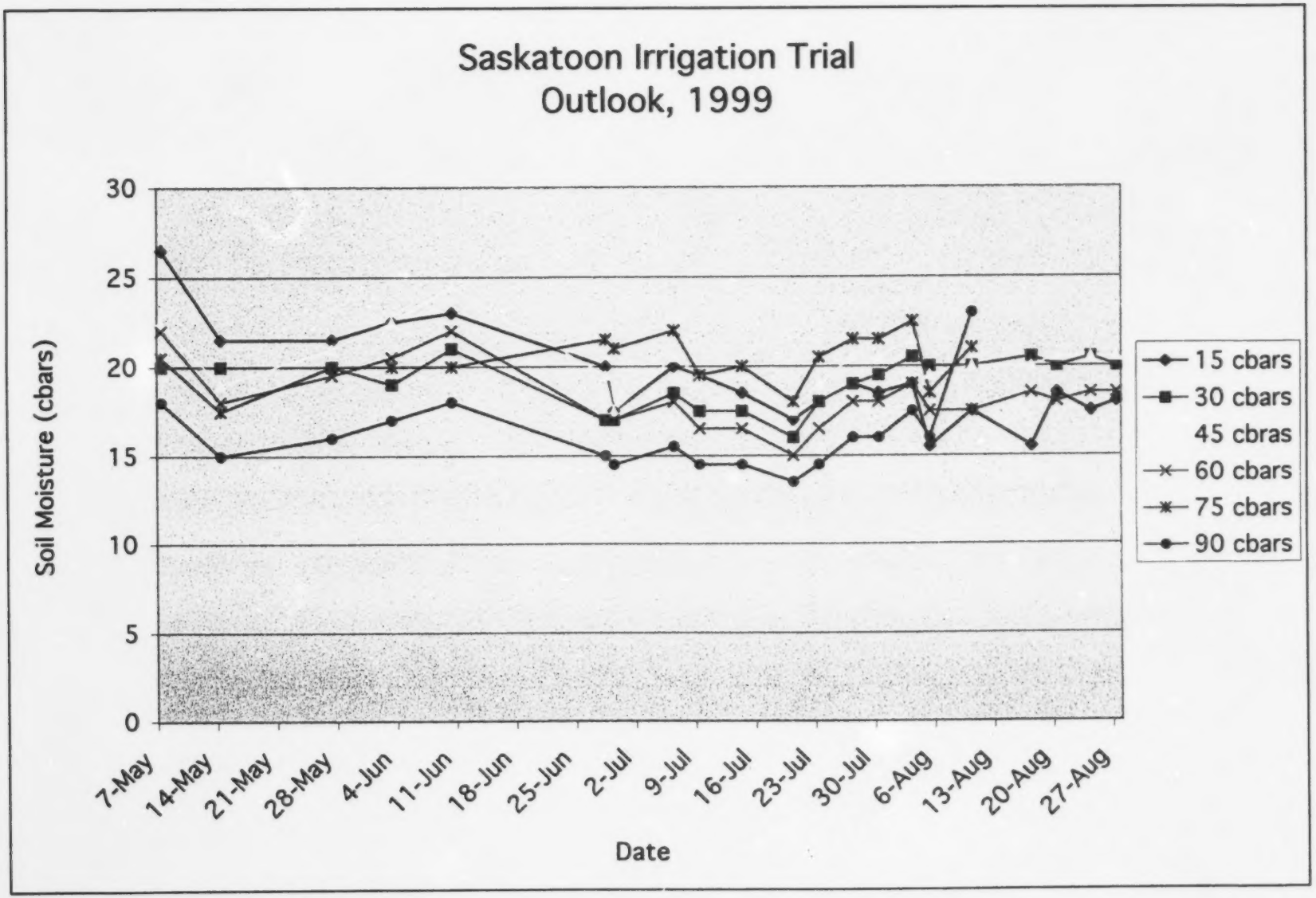


Figure 10. Summary of irrigation treatments at Outlook in the chokecherry irrigation trial, 1999.

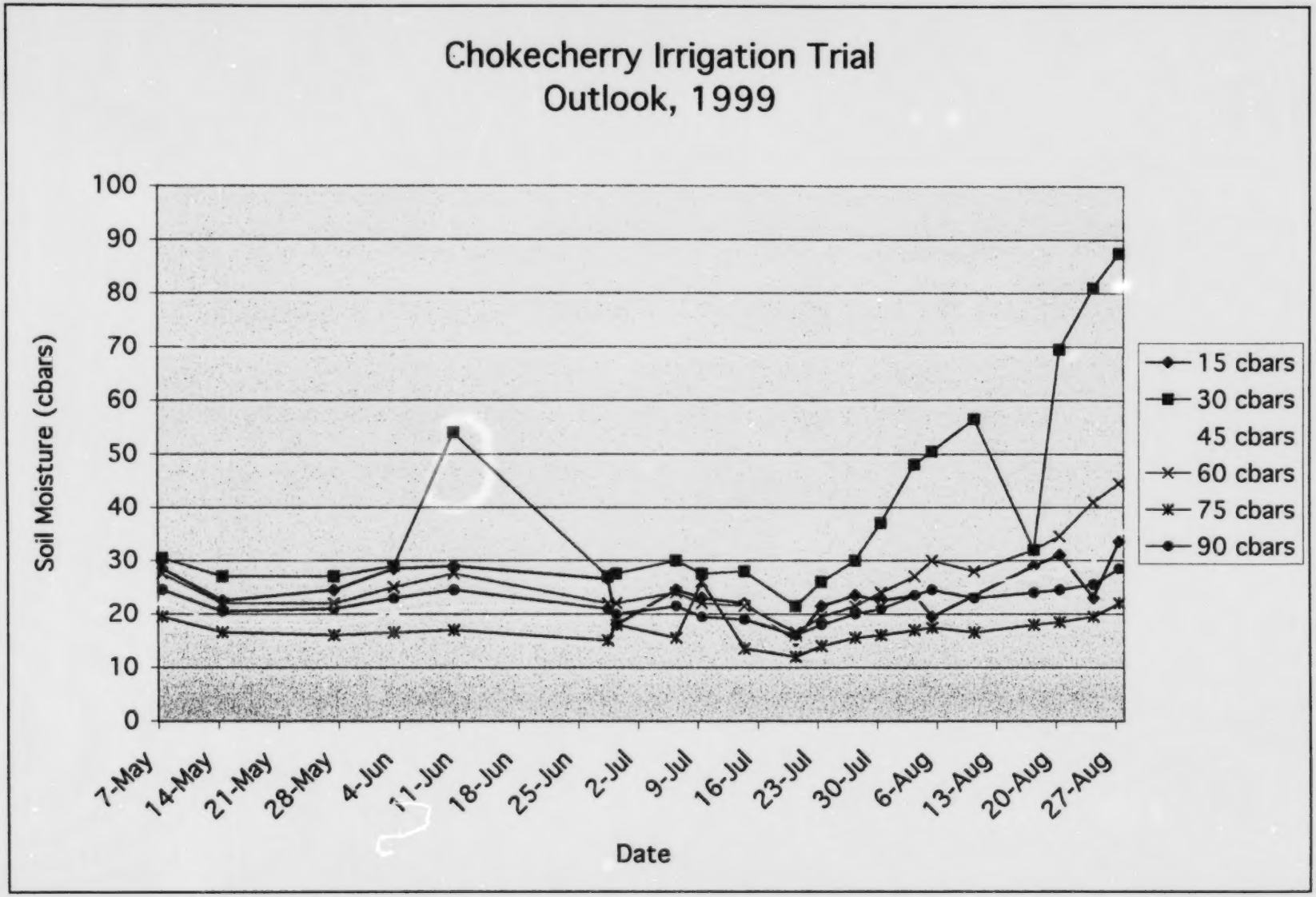


Figure 11. Summary of irrigation treatments applied at Indian Head in the saskatoon irrigation trial, 1999.

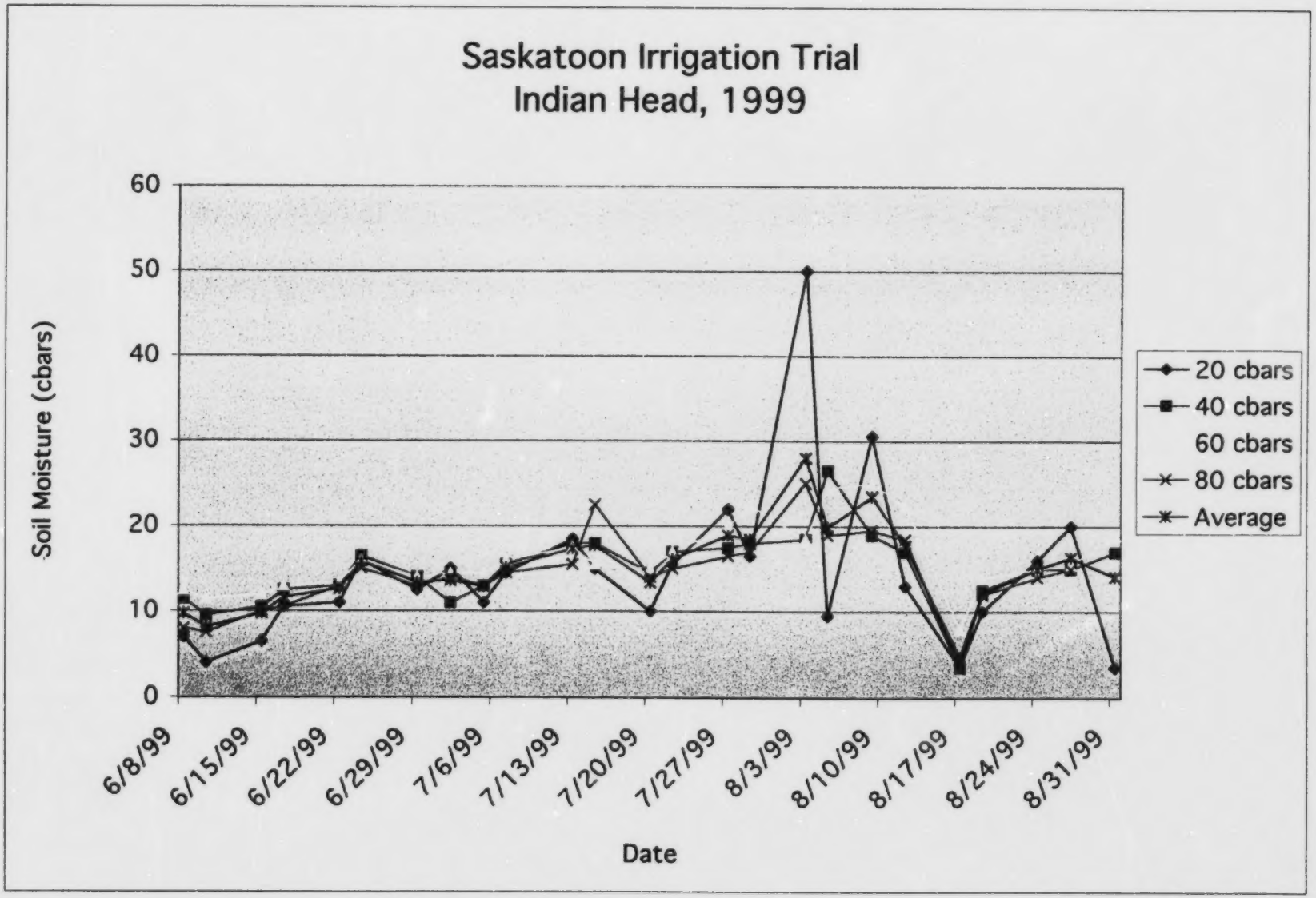


Figure 12. Summary of irrigation treatments applied at Indian Head in the chokecherry irrigation trial, 1999.

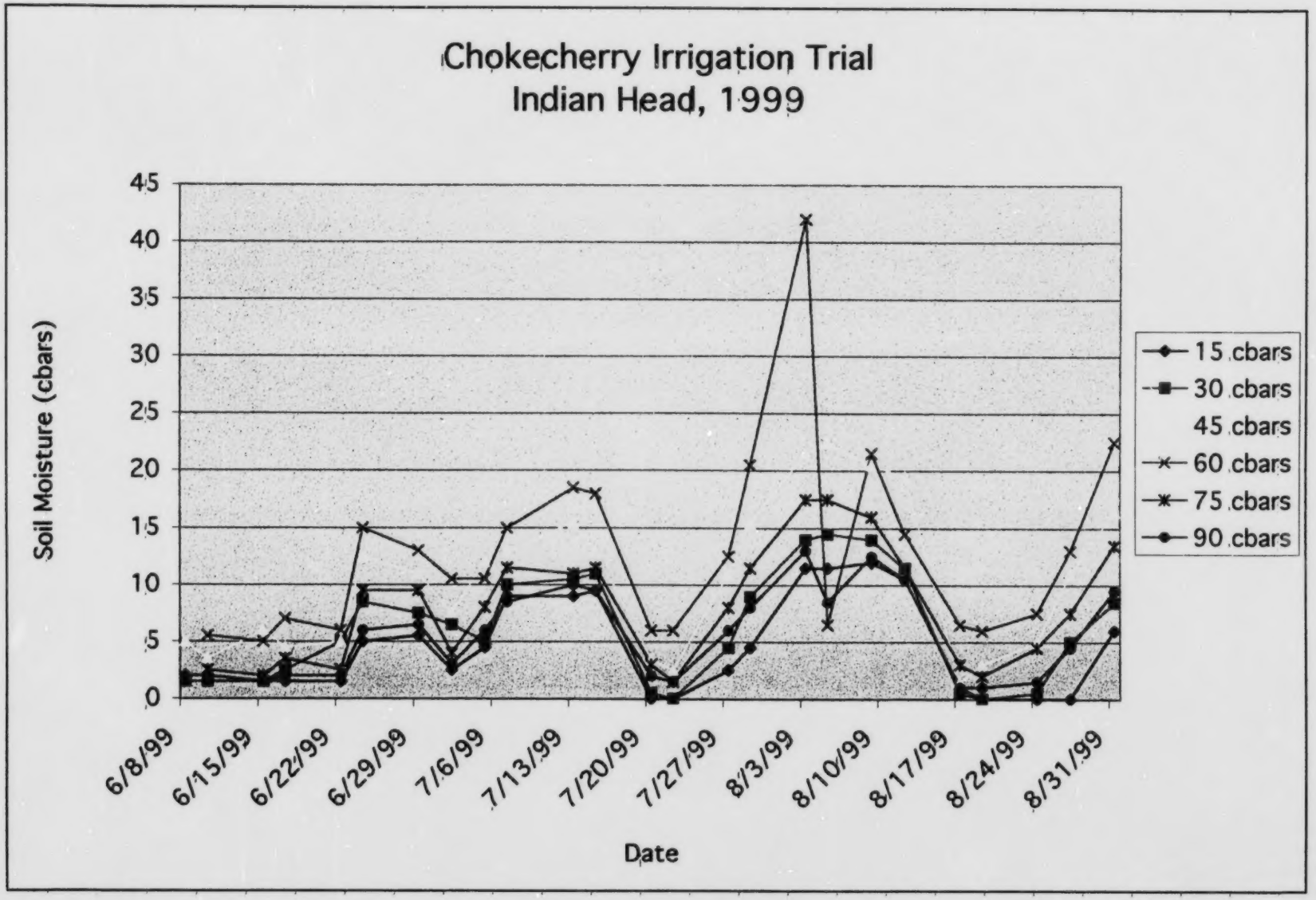


Table 8. Survival, growth and yield results from chokecherry irrigation trials (Indiand Head and Outlook, 1999).

Site	Treatment (cbars)	Suvival (%)	Shoot Growth (cm)	Sucker #	Yeild (Kg per plant)	Fruit # per cup
Indian Head	15	100 +/- 0	48.2 +/- 4.8	0.1 +/- 0.1	0	na
	30	100 +/- 0	47.6 +/- 7.6	0.3 +/- 0.3	0	na
	45	100 +/- 0	43.4 +/- 3.1	0 +/- 0	0	na
	60	100 +/- 0	45.2 +/- 5.3	0.2 +/- 0.2	0	na
	75	100 +/- 0	45.1 +/- 4.5	0.5 +/- 0.6	0	na
	90	100 +/- 0	43.3 +/- 3.9	0.5 +/- 0.9	0	na
Outlook	15	100 +/- 0	39.3 +/- 2.2	2.2 +/- 1.5	2.0 +/- 0.6	192 +/- 10
	30	100 +/- 0	37.7 +/- 6.6	2.3 +/- 1.2	2.4 +/- 0.8	203 +/- 4
	45	100 +/- 0	38.7 +/- 8.8	3.0 +/- 1.2	1.7 +/- 0.7	193 +/- 7
	60	100 +/- 0	35.2 +/- 2.8	2.1 +/- 2.0	3.1 +/- 1.7	205 +/- 19
	75	100 +/- 0	32.3 +/- 5.7	5.7 +/- 1.4	1.8 +/- 0.4	219 +/- 21
	90	100 +/- 0	33.0 +/- 7.5	2.4 +/- 1.4	2.2 +/- 1.5	200 +/- 5

Mean of six replicates. +/- values are the standard deviation of the mean.

Table 9. Survival, growth and yield results from saskatoon irrigation trials (Indian Head and Outlook, 1999).

Indian Head						
Site	Treatment (cbars)	Suvival (%)	Shoot Growth (cm)	Sucker #	Yeild (Kg per plant)	Fruit # per cup
Indian Head	20	100 +/- 0	54.2 +/- 3.7	2.7 +/- 2.0	0	na
	40	100 +/- 0	53.9 +/- 5.5	1.4 +/- 1.3	0	na
	60	100 +/- 0	49.3 +/- 2.6	1.9 +/- 1.9	0	na

	80	100 +/- 0	42.8 +/- 12.7	3.0 +/- 3.7	0	na
Outlook	15	100 +/- 0	38.6 +/- 10.9	4.6 +/- 3.4	1.4 +/- 0.8	4.6 +/- 3.4
	30	100 +/- 0	31.4 +/- 5.9	3.3 +/- 2.1	1.3 +/- 0.5	3.3 +/- 2.1
	45	100 +/- 0	31.2 +/- 4.8	3.6 +/- 2.1	1.3 +/- 0.7	3.6 +/- 2.1
	60	100 +/- 0	36.0 +/- 6.7	2.2 +/- 1.1	1.4 +/- 0.7	2.2 +/- 1.1
	75	100 +/- 0	32.0 +/-3.7	3.7 +/- 1.9	0.9 +/- 0.4	2.2 +/- 1.1
	90	100 +/- 0	40.3 +/- 9.9	3.4 +/- 2.4	0.8 +/- 0.4	3.4 +/- 2.4
Mean of six replicates. +/- values are the standard deviation of the mean.						

Greenhouse Irrigation Trials

In setting up the initial greenhouse trial, a certain amount of trial and error was needed in order to properly place the soil moisture sensors to accurately reflect moisture in the root zone. Granular matrix sensors (Irrometer Co., CA) were used to measure the soil moisture level of each treatment. Initially each sensor was placed in a vertical orientation against the base of the root plug (Figure 13A) and then covered with soil. This presented a problem early in the trial, when on a bright day, many plants began to wilt even though soil moisture readings did not indicate a need to apply any of the treatments. It was apparent that the plug containing the root mass was drying more quickly than the soil surrounding the moisture sensor. More representative readings were taken when the sensors were placed horizontally, approximately 3 centimetres from the plug and 2 centimetres below the soil surface (Figure 13B). In this orientation, the side of the sensor closest to the soil surface sits approximately parallel to the top of the root plug of the transplant. If granular matrix sensors are used to determine irrigation needs of newly transplanted saskatoons, this method of placement is recommended.

The amount of new growth on the main shoot was monitored over the course of these trials (Figure 14). A relatively small increase in average shoot length was observed in the first greenhouse trial, however these plants were grown in the greenhouse for several weeks before being transplanted and a significant amount of growth (main shoot and branching) had already occurred prior to the commencement of the irrigation treatments. It is possible that the amount of growth that had taken place prior to transplanting had an impact on the kind of growth response that resulted after the treatments were applied. Had both sets of transplants been handled in the same fashion, the growth curves may have been more similar.

At the end of these trials plant height, stem caliper at soil level, fresh and dry top weight,

Figure13. Soil moisture sensor placement methods used to measure irrigation application point.

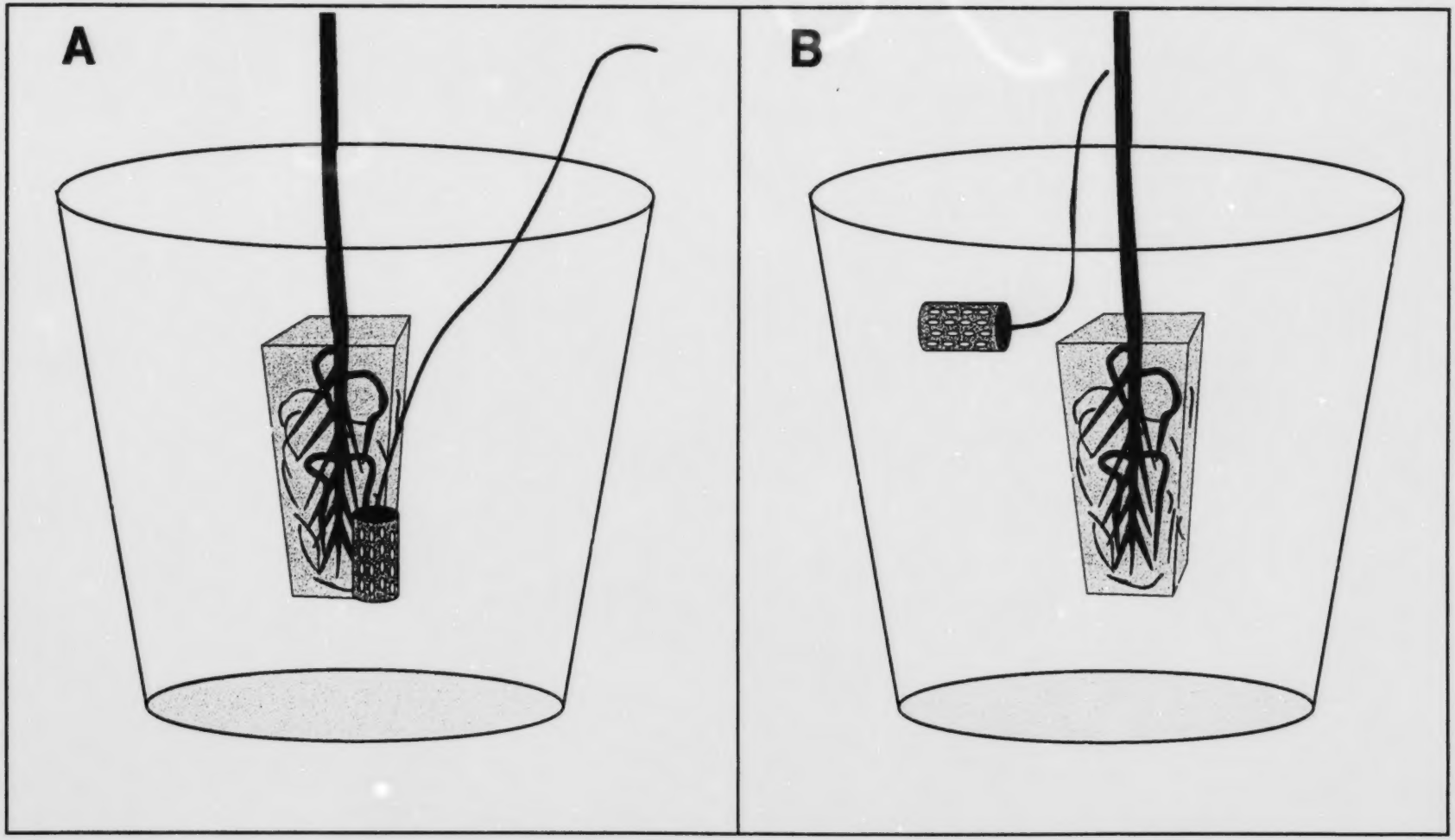
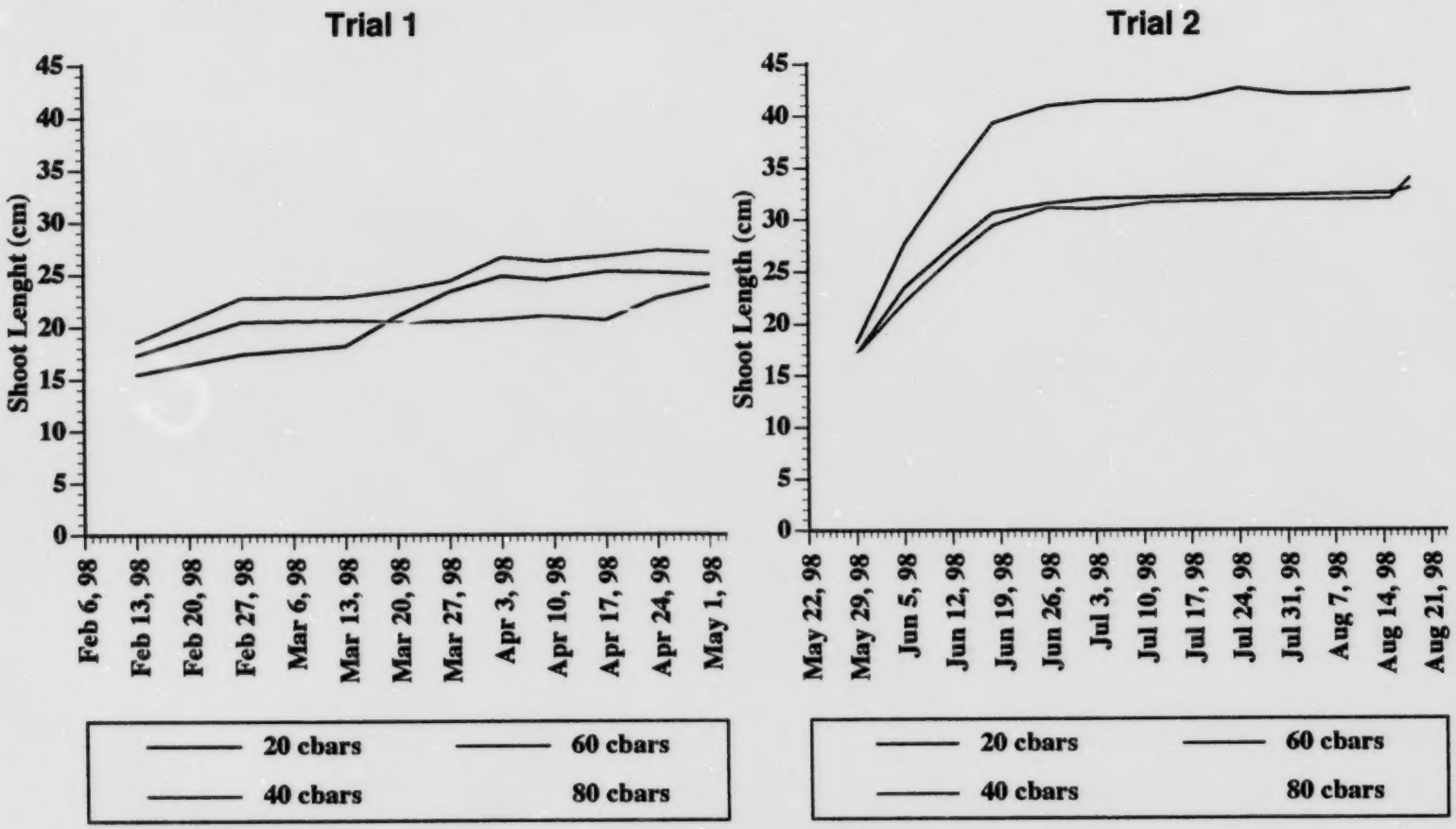


Figure 14. Effect of irrigation application point on length of terminal shoot.



and fresh and dry root weight data were collected (Table 1). Similar results were obtained from each experiment, however variability tended to be higher and growth lower in the second experiment. A severe spider mite infestation in the second trial may have contributed to the reduction in growth and increased plant variability. Reduced spider mite problems were observed for plants grown in the wettest (20 cbars) treatment.

Table 10. Effect of irrigation application point on plant height, stem caliper, fresh and dry top and root weight of greenhouse grown saskatoon plants.

Irrigation Point (centibars)	Measurement	Experiment 1	Experiment 2
20	Length (cm)	54.9 +/- 9.0	55.7 +/- 4.2
40		57.8 +/- 4.0	48.7 +/- 3.8
60		50.2 +/- 5.1	49.2 +/- 15.5
80		51.1 +/- 6.0	43.8 +/- 8.1
20	Caliper (cm)	7.9 +/- 0.8	7.5 +/- 0.4
40		8.0 +/- 0.4	7.3 +/- 0.8
60		7.4 +/- 0.5	6.7 +/- 0.8
80		7.2 +/- 0.6	7.1 +/- 0.9
20	Fresh Top Weight (g)	93.3 +/- 9.2	80.9 +/- 17.3
40		82.0 +/- 11.2	56.1 +/- 13.9
60		70.2 +/- 17.9	54.0 +/- 22.6
80		64.2 +/- 11.1	53.9 +/- 15.9
20	Dry Top Weight (g)	44.2 +/- 5.0	28.5 +/- 7.5
40		37.4 +/- 5.5	17.2 +/- 6.1
60		29.0 +/- 6.5	17.1 +/- 10.1
80		29.3 +/- 5.1	16.7 +/- 7.25
20	Fresh Root Weight (g)	139.6 +/- 16.7	88.5 +/- 23.5
40		111.9 +/- 26.4	67.0 +/- 16.1
60		89.8 +/- 13.3	67.0 +/- 26.3

80		80.3 +/- 10.2	64.7 +/- 20.0
20	Dry Root Weight (g)	32.6 +/- 4.4	10.7 +/- 4.9
40		29.2 +/- 6.4	6.1 +/- 3.1
60		26.3 +/- 7.2	7.6 +/- 5.1
80		21.5 +/- 3.4	6.0 +/- 4.6
Means of 5 replicates. +/- values are the standard deviation of the mean			

Plant height and stem caliper were least affected by the irrigation treatments (Figure 15). None of the irrigation treatments produced any differences in plant height in either trial but a correlation was detected between stem thickness and irrigation application point in the first trial, where increasing irrigation tended to increase stem thickness. No differences in stem caliper were detected between treatments in the second experiment.

Higher soil moisture levels increased top growth in both experiments (Figure 16). This was most obvious from the results obtained in the first irrigation trial. In general, plant growth during the first trial was much higher and less variable. The negative impact of the spider mite infestation may have reduced the vigour of the plants grown in the second experiment.

Root growth varied considerably between the two greenhouse trials (Figure 16). A strong correlation between irrigation application point and root growth was detected in the first trial. A trend toward increased root growth at the wettest irrigation point was observed in the second trial but the results were too variable to confirm this statistically.

Based on the results of these two irrigation trials, irrigation application points between 20 and 40 centibars should be used on newly planted saskatoon plants. Care should be taken to place soil moisture sensors near the soil surface since this region more accurately reflects the dehydration rate of the root plug. If bare root transplants are used, it would be possible to place the soil moisture sensor inside the transplant's root zone, which should provide accurate readings.

During the first greenhouse trial, some leaf yellowing was observed in the wettest irrigation treatments, likely due to the leaching of nitrogen. A mid-season application of nitrogen, either through irrigation water or applied to the soil surface may be required to alleviate this problem. To avoid waterlogging effects, care should be taken to avoid applying much more water than is needed to wet the soil surrounding the root plug. This is especially true in heavy soils and as the irrigation application point approaches 20 centibars. Irrigation applications at soil moisture levels greater than 60 centibars will likely reduce growth, increase plant stress and may

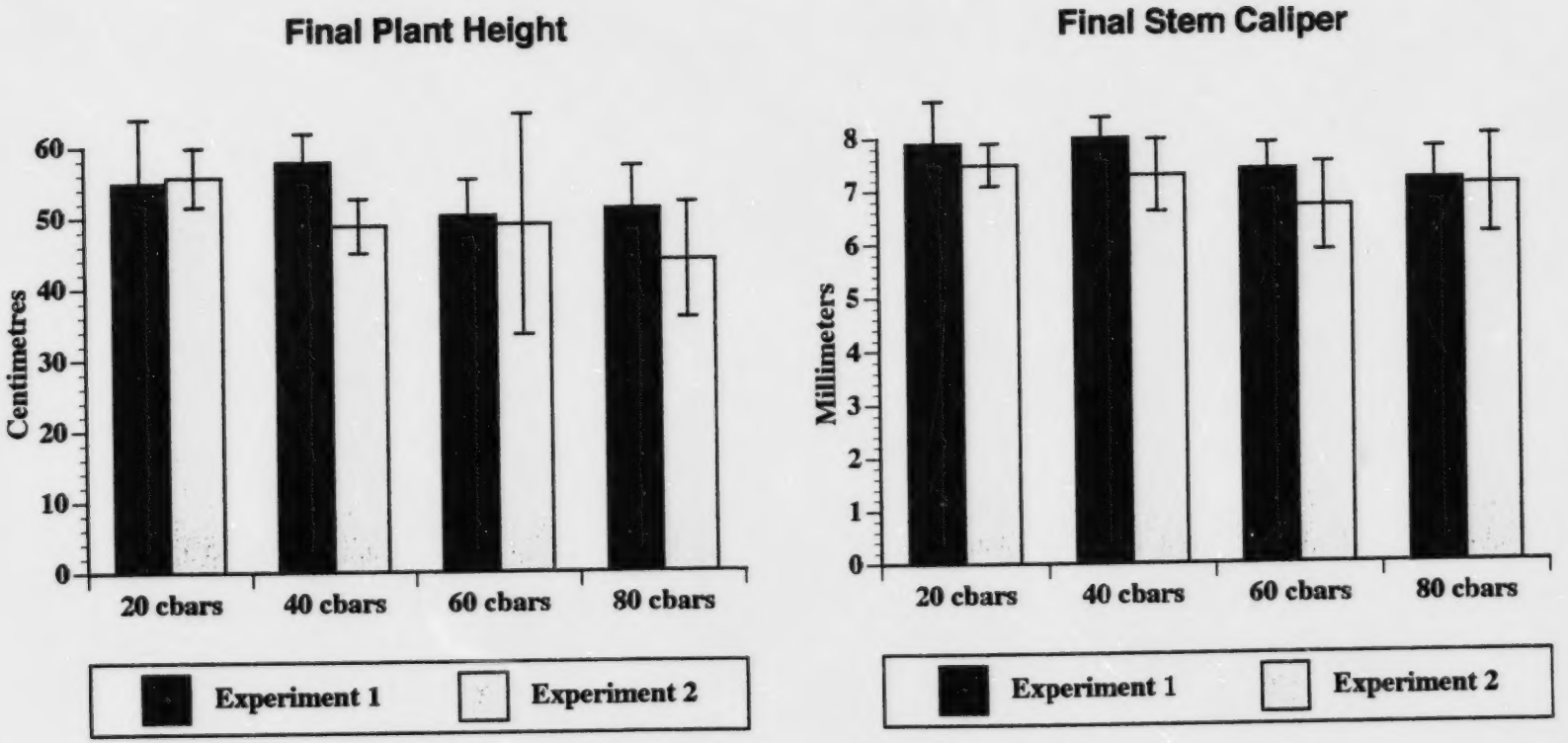


Figure 15. Effect of irrigation application point on plant height and stem caliper of greenhouse grown saskatoon plants.

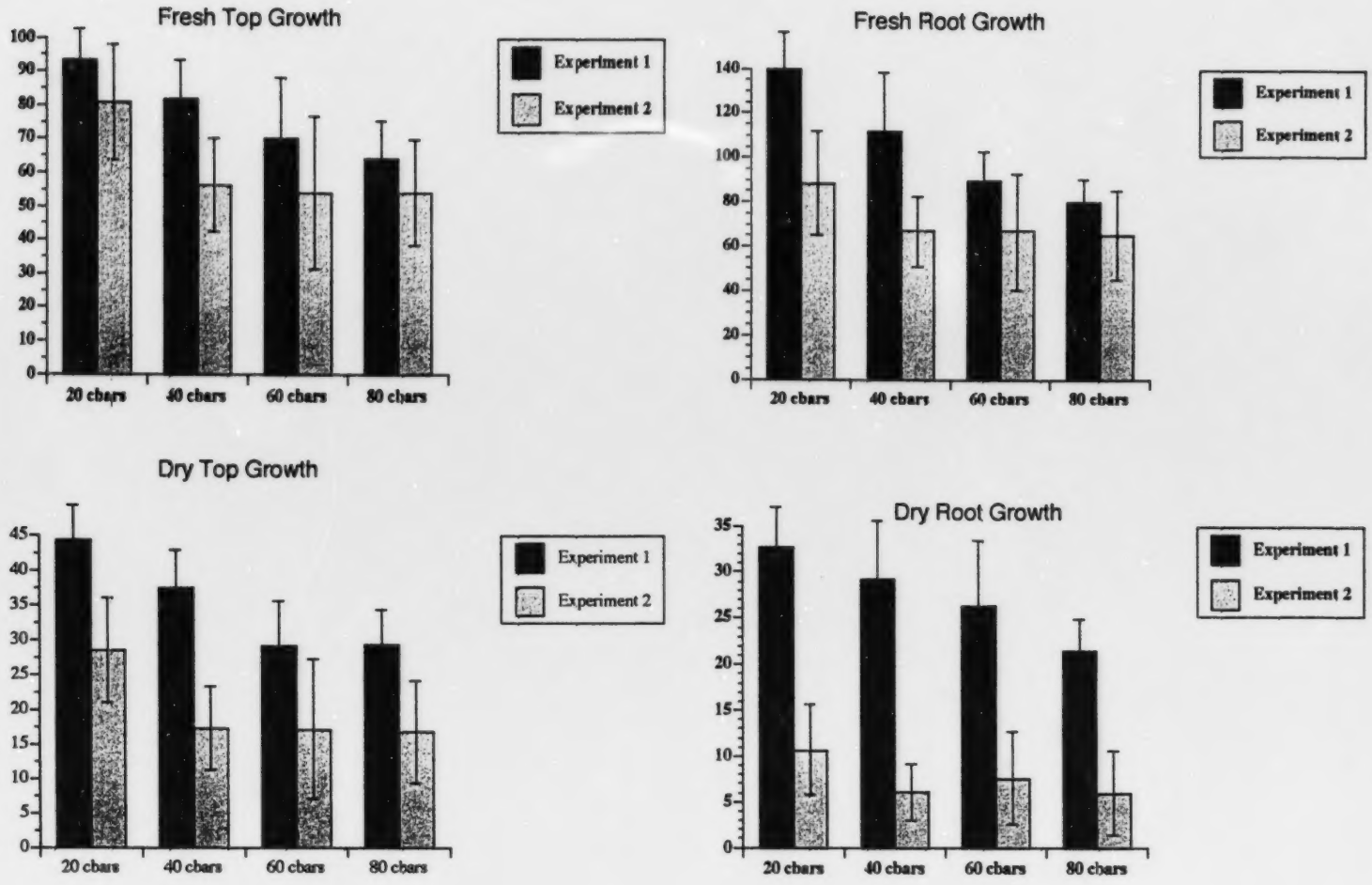


Figure 16. Effect of irrigation application point on fresh and dry top and root weight of greenhouse grown saskatoon plants.

increase spider mite susceptibility.

General Conclusions

Large amounts of precipitation received during the 1998 and 1999 seasons meant that it was not possible to determine the impact of irrigation on yield and growth in established saskatoon and chokecherry orchards. However, from the results of the additional greenhouse trials, and through observations made during the trial period, a number of general conclusions could be made. Soil moisture during May and early-June rarely required irrigation treatments to be applied. In the absence of rainfall, most soil moisture loss occurred during periods of rapid growth and fruit development, that is, during the months of June and July. In treatments of the field study of saskatoon and chokecherry, where soil moisture was depleted to levels above 60 centibars, it was noted that repeated irrigation applications were required to completely replenish soil moisture. This suggests that a typical trickle irrigation system may not be able to immediately supply adequate moisture if the soil is allowed to dry out excessively before the system is turned on. This is not surprising considering trickle irrigation systems are only designed to replenish soil moisture lost during a single day. This would also suggest that there may be risks associated with delaying irrigation applications if a grower is using a trickle irrigation system. Soil moisture levels which were maintained between 20 and 40 centibars produced the greatest amount of plant growth in saskatoon plants grown in the greenhouse. During these trials, soil moisture levels were monitored daily and were not allowed to stray far from the target treatment levels. Growers should be mindful of the importance of checking soil moisture levels daily in order consistently maintain the target soil moisture range. When using soil moisture sensors with recently transplanted saskatoons, it was found that placement of the sensing unit next to the base of the transplant's root plug would not accurately reflect water loss occurring inside the root plug. It was determined that the root plug of young saskatoon transplants dehydrate at the rate of soil near the top of the root plug even if soil near the base of the plug is adequately moist. To prevent root damage from dehydration in newly transplanted saskatoons, the moisture level of the soil near the top of the root plug must be monitored in order to determine irrigation requirements.

Based on the information gathered in this study, it is recommended that growers use soil moisture sensors in their orchards, and that soil moisture levels be maintained at the 20 to 40 centibar level at 5 to 30 cm soil depth, depending on plant size. New transplants should be monitored closely and irrigated every 1 to 2 days so as to ensure that the root plug does not dry out.

Fertilization

The fertilization component of this project involved the analysis of soil and leaf tissue for nutrient content in order to develop nutrient standards for growing saskatoons and chokecherries. In 1998 and 1999, the soil and foliar analysis project for saskatoons was divided into two parts: a) a simplified study in which grower's participated, and b) a more comprehensive study conducted by the Native Fruit Development Program. Additional saskatoon fertilization projects were also included in the project to further assist in the determination of fertilizer requirements for saskatoons.

Saskatoon Soil and Foliar Analysis - 1997

This project involved the analysis of soil and leaf tissue for nutrient content from saskatoon orchards at a number of locations on the prairies. Three growers from the Fruit Grower's Society of Alberta, five growers from the Saskatchewan Fruit Grower's Association, six grower's from Manitoba and the University of Saskatchewan were involved in this project. Manitoba growers were funded by the Prairie Fruit Growers Association, whereas all other growers were required to cover the costs of the analyses. Enviro-Test Laboratories (Saskatoon) offered a 50 % discount on all soil and tissue analyses for the project.

Standard foliar sampling protocol used for apple orchards was followed. Each grower selected one or more blocks from their orchard from which five trees were selected in a specified pattern. From these selected plants, leaf samples were taken periodically throughout the summer. Soil was sampled from under these plants at two depths (0-9 in. and 9-18 in.) both in the spring and in the fall. All soil and leaf samples were analyzed for both macro and micronutrients. Current season's shoot growth was measured and fruit yield recorded. A list of the growers involved and the foliar samples submitted from each are presented in Table 11.

Foliar nutrient levels were calculated for each month and are presented in Table 12. In general, foliar nitrogen (N), phosphorus (P), potassium (K), and sulphur (S) decreased, and calcium (Ca), magnesium (Mg), iron (Fe), and manganese (Mn) increased as the season progressed. The change in leaf N, P, and K throughout the season is shown is Figure 17. The most dramatic change in foliar nutrient levels occurred in June. Seasonal trends in foliar nutrient levels throughout the growing season have been found to occur in other fruit trees. For this reason, leaves were sampled periodically throughout the growing season in order to determine at what time nutrient levels are most stable. However, in this study the changes in nutrient levels from month to month are not only a reflection of seasonal changes, but also the result of variation among locations because not all the same sites are represented each month. In general, leaf nitrogen and phosphorus levels differed little among differing cultivars and locations, whereas, leaf micronutrient content showed greater fluctuations among cultivars and locations.

Because leaf samples came from both fertilized and unfertilized orchards, nutrient levels

Table 11. The dates of foliar sampling of various saskatoon cultivars as submitted by growers for the soil and foliar analysis project in 1997.

Grower	Location	Cultivar	Foliar Sampling Dates[1]							
			end May	mid-Jun	end Jun	mid-Jul	end Jul	mid-Aug	end Aug	mid-Sep
Shirley Alton	Ardrossan, AB	Smoky		*				*		
Arden Delidais	Elnora, AB	Smoky (1a)[2] Smoky (1b) Smoky (2)		* * *		* * *				
Geroge Monner	Fairview, AB	Smoky		*		*		*		
Gary Giroux	Moose Jaw, AB	Martin (1) Martin (2)				* *				* *
Bill King	Outlook, SK	Smoky				*				
Linda Metke	Cadillac, SK	Smoky						*		*
Brian Topp	White City, SK	Smoky Thiessen	* *		* *	* *				* *
Lee Whittington	Saskatoon, SK	Smoky Thiessen						* *		
University of Saskatchewan	Saskatoon, SK	Honeywood Pembina Smoky Thiessen	* * * *	* * * *	* * * *	* * * *	* * * *	* * * *	* * * *	* * * *
Brian Anderson	Swan River, MB	Smoky		*		*				
John Froese	Altona, MB	Smoky		*	*	*	*	*		
Dirk Helms	Winnipeg, MB	Smoky Thiessen	* *	* *		* *				
Brian Hudon	Minnedosa, MB	Smoky		*	*	*	*			
Helen Penner	Niverville, MB	Smoky	*	*	*	*	*	*	*	*
John Ritz	Petersfield, MB	Smoky (1) Smoky (2)	* *				* *			

[1] Sampling dates are approximate.
[2] Numbers in brackets indicate orchard; letters indicate sample.

Table 12. Summary of monthly leaf nutrient levels for saskatoons in 1997.

Month	Statistic	N (%)[a]	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)[a]	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
June	Mean	3.59	0.37	1.64	0.24	0.90	0.46	8.26	95.64	249.92	29.88	54.81
	Median	3.63	0.39	1.53	0.23	0.88	0.47	7.21	74.71	85.43	27.37	48.05
	Range n[b] = 21	2.70 - 4.26	0.25 - 0.50	0.35 - 2.73	0.18 - 0.29	0.62 - 1.46	0.33 - 0.65	1.00 - 24.38	41.85 - 204.84	30.77 - 1124.60	17.92 - 51.89	23.92 - 127.44
July	Mean	2.95	0.23	1.32	0.19	1.52	0.56	5.80	124.81	358.92	20.39	33.83
	Median	2.89	0.22	1.33	0.19	1.51	0.48	5.71	109.61	180.97	18.14	34.15
	Range n = 20	2.45 - 3.69	0.16 - 0.31	0.63 - 2.48	0.16 - 0.23	1.03 - 2.10	0.37- 1.02	2.99 - 8.56	78.80 - 270.16	51.98 - 1396.09	11.94 - 58.31	20.94 - 58.03
Aug.	Mean	2.44	0.18	1.12	0.16	1.74	0.63	5.82	118.95	239.34	24.84	33.20
	Median	2.41	0.18	1.15	0.16	1.76	0.54	5.99	99.21	153.00	17.86	28.38
	Range n = 11	2.09 - 2.88	0.13 - 0.26	0.75 - 1.44	0.13 - 0.22	1.25 - 2.25	0.33 - 1.22	2.98 - 8.41	83.92 - 250.85	49.60 - 733.94	14.16 - 56.84	25.84 - 72.80
Sept.	Mean	2.03	0.14	0.70	0.13	1.91	0.81	6.54	114.09	188.44	15.04	27.41
	Median	2.12	0.15	0.69	0.14	2.05	0.89	6.47	109.45	199.67	13.43	25.90
	Range n = 5	1.68 - 2.17	0.12 - 0.17	0.46 - 1.08	0.12 - 0.15	1.43 - 2.34	0.35 - 1.21	5.47- 7.44	95.73 - 150.35	81.51 - 333.81	12.45 - 21.01	24.86 - 30.66

a. % = % dry weight; ppm = parts per million.
b. n indicates the number of sites from which the data was obtained.

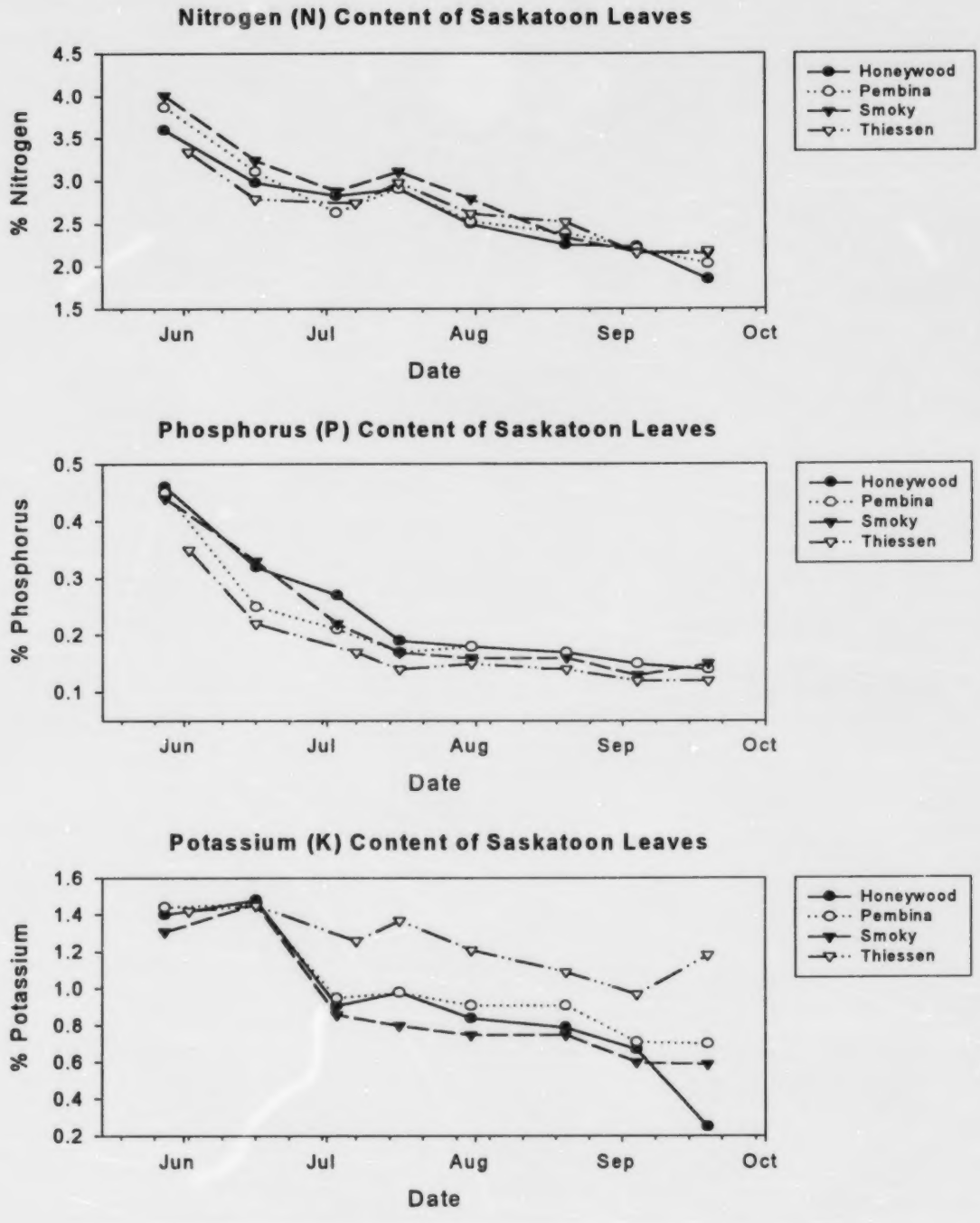


Figure 17. Nitrogen, phosphorus and potassium content of saskatoon leaves sampled by the University of Saskatchewan from May to September of 1997. The cultivars, Honeywood, Pembina, and Smoky were sampled from the University orchard in Saskatoon; Thiessen was sampled from an orchard outside of Saskatoon.

of N and P from both fertilized and unfertilized orchards were calculated and are presented in Table 13. Although the mean leaf nutrient level from fertilized plants tended to be consistently higher than those from unfertilized ones, this increase was not significant due to the high amount of variation from each set of samples that can be seen in the range of values for each month. As well, these figures are only truly comparable if they had been derived from fertilized and unfertilized shrubs from the same sites, however, each set also represents different locations, and different fertilization schemes. Thus, no sound conclusions can be drawn from this data as to the effect of fertilization on foliar nutrient levels in saskatoon plants.

No strong relationship was found between foliar and soil nutrient levels. However, a relationship has not always been found in past research between soil and foliar nutrients, particularly for other perennial fruit crops due to the effects of stored nutrients in the plants from the previous season. In addition, any fertilizer applied after the soil test in the spring would not be represented in the soil test, but may have had an effect on leaf nutrient concentrations. Too few unfertilized orchards were available to do an accurate analysis solely on these.

No relationship was found between yield or shoot growth and foliar nutrient levels. This was likely due to a large number of variables inherent in the study such as the effect on yield and growth of the different environments, plant ages, cultivars, and different cultural practices associated with each orchard.

To address some of these sources of variability it was decided that in the following seasons more intensive research would be conducted by the Native Fruit Development Program to examine the relationships between soil and foliar nutrient levels and plant response. The growers' participation in the project would also be simplified so that only one soil and foliar sample would be required.

Saskatoon Soil and Foliar Analysis - 1998 & 1999

Saskatoon Soil and Foliar Analysis from Grower's Orchards

This aspect of the project involved the participation of a number of saskatoon growers. Three growers from the Fruit Grower's Society of Alberta, five growers from the Saskatchewan Fruit Grower's Association, and the University of Saskatchewan were involved in the project. The growers did all sampling themselves and covered the costs of the analyses. Enviro-Test Laboratories (Saskatoon) offered a 50 % discount on all soil and tissue analyses for the project.

In 1997, leaf samples were taken up to every two weeks throughout the season. This was necessary to determine when leaf nutrient levels were most stable for sampling. This time was determined to be from the end of July until the middle of August. Therefore, in 1998 and 1999 growers were requested to submit only one foliar and one soil sample two weeks after harvest.

Each grower selected one or more blocks from their orchard from which five trees were selected in a specified pattern. From these selected plants, leaf samples were taken after harvest was complete. Soil was sampled from under these plants at two depths (0-9 in. and 9-18 in.) at the same time. All soil and leaf samples were analyzed for both macro and micro-nutrients.

Table 14 shows the results of foliar analysis of saskatoons after harvest for 1997 to 1999 and the average of the three years combined together. For the most part, these leaf nutrient ranges were comparable to that of apple. The upper ranges of leaf iron and manganese levels were quite high but this is likely due to contamination. In the case of iron, any dusting of soil on the leaves will yield very high levels of iron. It is speculated that leaf manganese levels may be elevated in orchards close to busy roads or highways due to the manganese content in the exhaust from vehicles.

The relationship between foliar and soil nutrient levels was examined using Pearson correlation analysis. Few significant correlations were found, however, only 14 sets of foliar and soil data were available for analyses in 1998 and 12 sets in 1999. A larger number of samples may have revealed more correlations. The following correlations were found in 1998. Leaf phosphorus content was correlated with that in the soil in the second depth ($r=0.77$). Sulphur levels in the first soil depth was correlated with that in the leaf ($r=0.66$). Leaf manganese content was correlated with that in both the first soil depth ($r=0.80$) and with the average of the two ($r=0.81$). Zinc content in the second soil depth was correlated with that in the leaves ($r=0.66$). Even fewer correlations were significant in 1999. In this year, leaf phosphorus was correlated with that in the soil in the second depth ($r=0.65$), and in the average of the two depths ($r=0.69$). Leaf copper was negatively correlated with soil copper levels in the first and second depths ($r=-0.59$ and -0.61, respectively). It is not known why this negative correlation would occur. The lack of relationship between soil and leaf nutrient concentrations likely reflects a large degree of variability due to different environments, cultivars and management practices. Sampling from a much larger number of orchards may be necessary to overcome the large degree of variability.

Saskatoon Soil and Foliar Analysis: A Comprehensive Study

A more comprehensive study was conducted by the Native Fruit Development Program in which saskatoon leaf and soil samples were collected from three sites. Samples were collected from the cultivars Honeywood, Pembina and Smoky in the University research plots in Saskatoon, and from the cultivar Thiessen at Moonlake, near Saskatoon. Samples were also collected from a fertilized orchard in Prince Albert (cultivar Smoky). Leaf samples were collected from these sites every two weeks. Due to heavy disease levels of *Entomosporium* leaf and berry spot in 1999, leaf samples were not able to be collected in September of that year. A soil sample was also collected at each site after the completion of harvest. Other data recorded from these sites included the length of the current season's shoot growth, and the number of flowers per cluster.

Table 13. Leaf nitrogen (N) and phosphorus (P) content of fertilized and unfertilized saskatoon trees in 1997.

Month	Statistic	N[a]		P	
		Unfertilized	Fertilized	Unfertilized	Fertilized
June	Mean	3.42	3.61	0.36	0.41
	Median	3.33	3.69	0.37	0.40
	Range	3.09 - 4.01 (n[b] = 6)	2.70 - 4.41 (n = 15)	0.28 - 0.43 (n = 6)	0.25 - 0.55 (n = 12)
July	Mean	2.78	2.95	0.21	0.22
	Median	2.75	2.88	0.19	0.22
	Range	2.60 - 2.96 (n = 6)	2.45 - 3.69 (n = 14)	0.17 - 0.27 (n = 6)	0.18 - 0.29 (n = 11)
Aug.	Mean	2.26	2.43	0.15	N/A[c]
	Median	2.32	2.37	0.15	N/A
	Range	1.97 - 2.57 (n = 7)	2.09 - 2.88 (n = 4)	0.13 - 0.18 (n = 7)	N/A

a. Nutrient levels of N and P as % dry weight.
b. n indicates the number of sites from which the data was obtained.
c. Data not available.

Table 14. Saskatoon foliar nutrient levels as sampled after harvest for 1997 to 1999.

Year	Statistic	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
1997[1]	Mean	2.5	0.17	1.1	0.17	1.8	0.66	6.3	115	198	23	33
	Median	2.5	0.18	1.1	0.17	1.9	0.64	6.5	104	126	18	29
	Min	2.1	0.13	0.75	0.13	1.3	0.35	4.0	78	50	11	26
	Max	2.9	0.23	1.4	0.22	2.3	1.22	8.9	180	734	57	59
	Standard Error	0.07	0.009	0.078	0.008	0.12	0.087	0.56	11.4	64.9	4.1	3.2
1998[2]	Mean	2.4	0.18	1.2	0.14	1.4	0.49	10.5	145	229	21	21
	Median	2.4	0.16	1.2	0.14	1.5	0.48	7.8	120	130	15	21
	Min	2.1	0.13	0.75	0.12	1.1	0.30	2.3	77	43	10	9
	Max	2.6	0.27	1.6	0.17	1.8	0.79	29	250	780	53	37
	Standard Error	0.04	0.010	0.068	0.004	0.06	0.038	1.75	14.7	56.1	3.9	2.3
1999[3]	Mean	2.4	0.20	1.1	0.15	1.6	0.53	7.0	103	151	22	24
	Median	2.4	0.18	1.1	0.15	1.6	0.54	6.0	63	120	14	25
	Min	2.1	0.14	0.71	0.08	1.2	0.31	3.9	38	56	8	20
	Max	2.9	0.28	1.6	0.19	2.1	0.82	17.8	237	465	79	29
	Standard Error	0.07	0.014	0.079	0.008	0.08	0.048	1.14	22.0	34.4	6.1	1.1
1997 to 1999[4]	Mean[5]	2.4	0.18	1.1	0.15	1.6	0.56	7.9	121	193	22	26
	Min	2.1	0.13	0.71	0.08	1.1	0.30	2.3	38	43	8	9
	Max	2.9	0.28	1.6	0.22	2.3	1.22	29	250	780	79	59

1. Data based on 10 samples from 7 sites.
2. Data based on 15 samples from 9 sites.
3. Data based on 11 samples from 9 sites.
4. Only 6 samples from 4 sites are common among the 3 years.
5. The mean was calculated by averaging the mean of each year.

Average foliar nutrient levels were calculated for each month. Results from 1998 are presented in Table 15, and from 1999 in Table 16. The results from the Prince Albert site were not included in the 1998 averages as these trees were regularly foliar fertigated and had abnormally high foliar nutrient levels. However, these trees were not fertigated in the following year, and the data from this site were included in the results for 1999. Leaf nutrient content tended to follow the same trend as was observed during the first growing season in which foliar nitrogen (N), phosphorus (P), potassium (K), and sulphur (S) decreased, and calcium (Ca), magnesium (Mg), and manganese (Mn) increased as the season progressed. In 1998 iron (Fe) increased, but tended to fluctuate in 1999. Zinc (Zn) increased in 1998 but decreased slightly in 1999 with the progression of the season. Boron (B) and Copper (Cu) levels tended to fluctuate in 1998, but decreased in 1999. Overall, the micronutrients do not appear to follow a consistent trend throughout the season, but tend to fluctuate. The change in leaf N, P, and K throughout the season in 1998 and 1999 is shown in Figures 18 and 19, respectively. The high nutrient levels of the fertilized saskatoons at Prince Albert are clearly seen in 1998 graphs, however, in 1999, the initial nutrient levels of these saskatoons were high in the spring as a carry over effect of the previous season's fertilization but decreased to normal levels by August. Overall, the most dramatic change in foliar nutrient levels occurred in the spring. Seasonal trends in foliar nutrient levels throughout the growing season have been found to occur in other fruit trees, and to follow similar patterns.

Correlation analysis was also done between data on the number of flowers per cluster and leaf nutrient content in 1998. No significant correlations were found, however, this was likely due to the very small sample size of five, and the fact that cultivar differences may have masked the effect of the nutrients on flower number. For these reasons, this was not done in 1999.

The current season's shoot growth was also compared to the soil and leaf nutrient levels using correlations. Due to the very small sample size (five), few or no significant correlations were found. The length of the current season's shoot growth was significantly correlated with leaf nitrogen ($r=0.99$) on August 12, and with leaf sulphur content ($r=0.98$) at the end of July in 1998. Although no other significant correlations were found, N, K and S tended to have high correlation coefficients (r values) for most of the dates that year. For example, between the end of June until the end of August, the average correlation coefficients for current season's shoot growth and leaf N, K, and S were 0.90, 0.89 and 0.79, respectively. In 1999, correlation analysis was also conducted on soil and leaf data collected in August. No significant correlations were found between current season's shoot growth and leaf nutrient content in August. However, correlation coefficients were relatively high between current season's shoot growth and leaf N ($r=0.79$) and leaf K ($r=0.72$). No correlations were found between soil nutrient levels and current season's shoot growth in both years. A study using only one cultivar from a larger number of orchards may have resulted in significant correlations between nutrient levels and growth or flowering.

Table 15. Summary of monthly leaf nutrient levels for saskatoons in 1998.

Month	Statistic	N (%)[a]	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)[a]	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
May	Mean	3.3	0.31	1.3	0.17	0.77	0.45	10	84.5	74.3	25.5	27.5
	Median	3.3	0.32	1.3	0.17	0.75	0.48	10	56.7	66.5	24	29.5
	Range n[b] = 4	3.2 - 3.4	0.23 - 0.36	1.1 - 1.4	0.15 - 0.19	0.59 - 0.97	0.31 - 0.51	10 - 10	54.4 - 170	34 - 130	22 - 32	12 - 39
June	Mean	2.5	0.19	1.1	0.14	1.14	0.34	14.3	88.2	94.3	16.3	17.8
	Median	2.6	0.19	1.1	0.14	1.15	0.67	12	85.9	77.5	16	18.5
	Range n = 8	2.4 - 2.6	0.15 - 0.24	0.96 - 1.3	0.13 - 0.17	0.8 - 1.5	0.53 - 0.56	10 - 20	43.7 - 158	39 - 190	12 - 22	1 - 27
July	Mean	2.4	0.14	0.88	0.13	1.36	0.58	11.8	87.5	127.6	15.7	17.6
	Median	2.4	0.15	0.86	0.13	1.35	0.63	9.3	83.5	115	13	16.5
	Range n = 8	2.2 - 2.6	0.12 - 0.16	0.69 - 1.1	0.12 - 0.14	0.99 - 1.7	0.34 - 0.79	6.9 - 29	38 - 160	53 - 230	3.9 - 53	12 - 24
Aug.	Mean	2.3	0.15	0.89	0.13	1.6	0.62	10.5	101.5	172.1	14.4	23.4
	Median	2.3	0.15	0.87	0.13	1.7	0.65	10.5	97	135	14.5	23.5
	Range n = 8	2.1 - 2.4	0.12 - 0.16	0.68 - 1.2	0.12 - 0.15	1.1 - 2.1	0.35 - 0.87	1 - 15	66 - 130	68 - 360	11 - 17	12 - 43
Sept.	Mean	2.1	0.13	0.71	0.12	1.73	0.62	8.1	111.3	184.8	9.5	20
	Median	2.1	0.14	0.67	0.12	1.75	0.65	7.8	110	155.0	12	20
	Range n = 4	1.9 - 2.2	0.11 - 0.14	0.52 - 0.98	0.11 - 0.14	1.2 - 2.2	0.35 - 0.84	6.7 - 9.9	95 - 130	69 - 360	1 - 13	12 - 28

a. % = % dry weight; ppm = parts per million.

b. n indicates the number of samples from which the data was obtained; sampling was done every 2 weeks from four sites.

Table 16. Summary of monthly leaf nutrient levels for saskatoons in 1999.

Month	Statistic	N (%)[a]	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)[a]	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
June	Mean	2.9	0.25	1.3	0.18	0.94	0.45	13.0	59	74	18	26
	Median	2.8	0.24	1.2	0.19	0.86	0.43	10.5	60	57	17	27
	Range n[b] = 10	2.4 - 3.8	0.18 - 0.36	1.1 - 1.8	0.15 - 0.23	0.51 - 1.7	0.28 - 0.67	2.9 - 30	43 - 77	29 - 190	14 - 24	9 - 37
July	Mean	2.7	0.19	1.1	0.17	1.4	0.54	7.5	82	114	18	22
	Median	2.8	0.20	1.1	0.17	1.4	0.53	6.9	64	100	16	21
	Range n = 10	2.5 - 3.0	0.15 - 0.21	0.87 - 1.4	0.15 - 0.21	0.95 - 1.9	0.31 - 0.81	4.9 - 13	45 - 250	46 - 250	11 - 41	14 - 30
Aug.	Mean	2.4	0.17	0.96	0.15	1.5	0.51	6.2	54	99	16	21
	Median	2.5	0.18	0.96	0.15	1.6	0.5	6.2	56	91	16	21
	Range n = 8	2.3 - 2.6	0.13 - 0.19	0.71 - 1.1	0.13 - 0.17	1.1 - 2.1	0.34 - 0.82	4.9 - 8.9	38 - 65	54 - 240	13 - 21	19 - 25

a. % = % dry weight; ppm = parts per million.
b. n indicates the number of samples from which the data was obtained; sampling was done every 2 weeks from four sites.

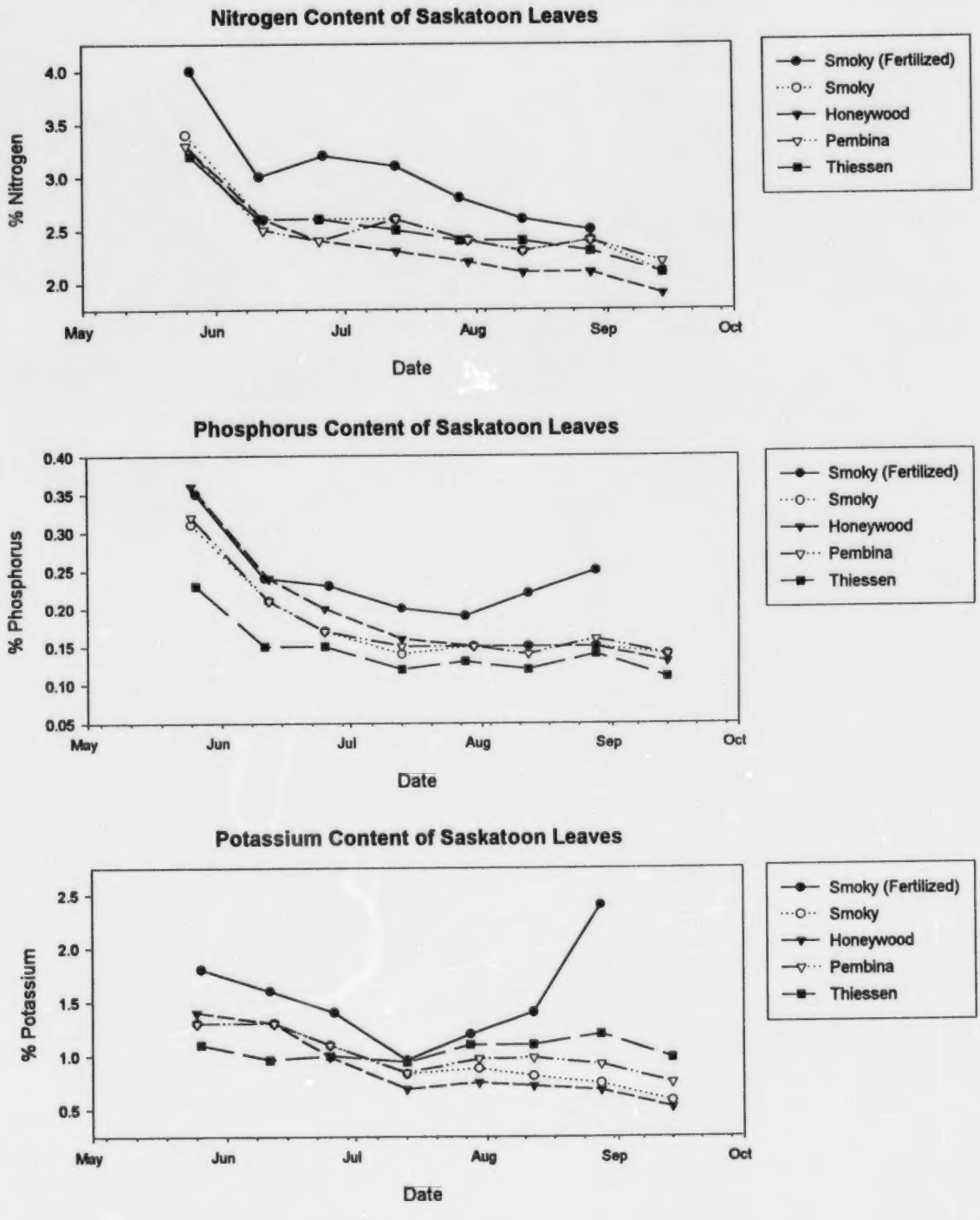


Figure 18. Nitrogen, phosphorus, and potassium content of saskatoon leaves throughout the 1998 season. The cultivars Smoky, Honeywood and Pembina are located at the University of Saskatchewan research plots in Saskatoon. Smoky (fertilized) is located at Prince Albert, and Thiessen at Moonlake, near Saskatoon.

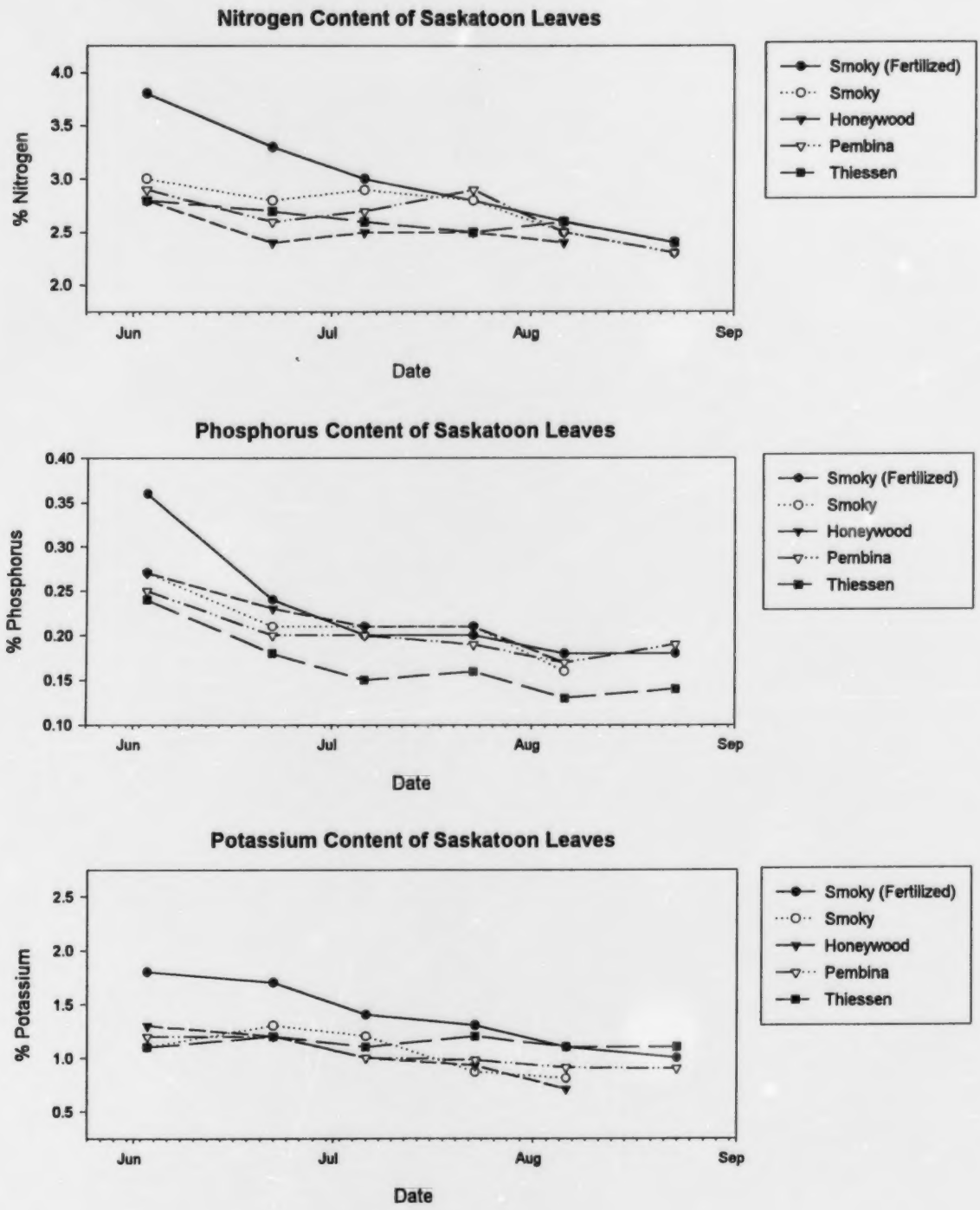


Figure 19. Nitrogen, phosphorus, and potassium content of saskatoon leaves throughout the 1999 season. The cultivars Smoky, Honeywood and Pembina are located at the University of Saskatchewan research plots in Saskatoon. Smoky (fertilized) is located at Prince Albert, and Thiessen at Moonlake, near Saskatoon.

Chokecherry Foliar Analysis, 1998 & 1999

To develop standards for foliar nutrient levels in chokecherries, leaf samples were collected from chokecherries at three sites in Saskatchewan. These included: a) three cultivars (Robert, Goertz, and Garrington) from the University of Saskatchewan chokecherry cultivar trial; b) one cultivar (Garrington) from a grower's orchard in White City; and c) one cultivar (Garrington) from a grower's site in Ruddell. Leaf samples were collected from the mid-portion of a current season's shoot once per month from June until August in 1998 and 1999.

Results averaged over all sites and cultivars are presented in Tables 17 and 18, for 1998 and 1999, respectively. In 1998, foliar nitrogen and phosphorus levels decreased in August while those of potassium and sulphur were relatively stable throughout the season. Calcium, magnesium, manganese and boron tended to increase overall with the progression of the 1998 season, although some fluctuations did occur. Foliar copper levels showed an increase in August, while those of iron and zinc fluctuated throughout the season. In 1999, foliar nitrogen, phosphorus, potassium, sulphur, copper and zinc decreased with the season while calcium and magnesium levels increased. Iron, manganese and boron levels tended to fluctuate throughout the season. Seasonal changes in nutrient levels in fruit trees are normal. Overall, these seasonal nutrient trends are similar to that of saskatoons in which nitrogen, phosphorus, potassium and sulphur tend to decrease, calcium and magnesium increase, and the micronutrients tend to fluctuate. Seasonal trends of leaf nitrogen, phosphorus, and potassium content for both years are shown in Figure 20.

Leaf nutrient levels of chokecherry tended to be most stable in August. Therefore, this month would be the most suitable for foliar sampling and the development of foliar nutrient standards for chokecherry. Table 19 shows the foliar nutrient levels of the chokecherries sampled in August averaged over the two years. Although further sampling of chokecherries from a greater number of sites would be beneficial in refining the data, the results from these two seasons still give some indication of the typical foliar nutrient ranges for chokecherries.

Table 19. Foliar nutrient levels of chokecherry sampled in Aug. in 1998 and 1999.

	N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
Mean	2.6	0.19	0.96	0.13	2.9	0.49	13	93	73	12	49
Median	2.6	0.19	1.05	0.13	2.8	0.5	14	99	72	12	47
Min.	2.3	0.14	0.58	0.12	2.3	0.31	6	57	54	1	31
Max.	3	0.26	1.5	0.14	3.5	0.71	21	140	110	22	76
S.E.[1]	0.06	0.01	0.09	0	0.13	0.04	1.3	8.5	5.5	1.8	3.9

1. Standard error of mean. Means based on 10 samples.

Table 17. Summary of monthly leaf nutrient levels for chokecherry in 1998.

Month	Statistic	N (%)[a]	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)[a]	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
May 22	Mean	3.5	0.25	1.2	0.13	1.1	0.26	12	104	39	17	27
	Median	3.5	0.25	1.3	0.14	1.3	0.27	9	68	42	15	28
	Range n[b] = 5	3.2 - 3.6	0.15 - 0.34	1.0 - 1.4	0.09 - 0.15	0.72 - 1.3	0.19 - 0.30	4 - 20	47.6 - 228	19 - 64	6.7 - 31	12 - 45
June 22	Mean	3.3	0.23	0.97	0.13	2.0	0.36	13	87	62	11	27
	Median	3.2	0.23	0.96	0.13	2.0	0.38	10	93	64	11	24
	Range n = 5	3.1 - 3.6	0.21 - 0.27	0.83 - 0.99	0.12 - 0.14	1.4 - 2.3	0.24 - 0.39	10 - 20	72 - 99	45 - 84	7.8 - 15	23 - 38
July 20	Mean	3.3	0.29	1.1	0.14	1.6	0.36	12	78	55	18	51
	Median	3.3	0.29	1.1	0.14	1.6	0.36	12	79	49	15	48
	Range n = 5	3.0 - 3.6	0.24 - 0.34	0.85 - 1.2	0.13 - 0.14	1.1 - 2.2	0.25 - 0.56	4.5 - 19	61 - 100	43 - 78	12 - 29	45 - 64
Aug. 21	Mean	2.6	0.18	1.1	0.13	2.6	0.44	16	112	78	11	43
	Median	2.6	0.20	1.1	0.13	2.6	0.45	15	110	74	10	42
	Range n = 5	2.3 - 3.0	0.14 - 0.22	0.62 - 1.5	0.12 - 0.14	2.3 - 2.8	0.31 - 0.64	13 - 21	98 - 140	55 - 110	1 - 22	31 - 57

a. % = % dry weight; ppm = parts per million.
b. n indicates the number of sites from which the data was obtained.

Table 18. Summary of monthly leaf nutrient levels for chokecherry in 1999.

Month	Statistic	N (%)[a]	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	Cu (ppm)[a]	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
June 7	Mean	3.6	0.29	1.4	0.18	1.8	0.43	42	90	57	18	43
	Median	3.7	0.28	1.3	0.18	1.8	0.41	39	84	55	17	44
	Range n[b] = 5	3.2 - 3.7	0.26 - 0.34	1.2 - 1.6	0.16 - 0.20	1.4 - 2.0	0.35 - 0.55	30 - 63	77 - 120	50 - 66	13 - 25	37 - 49
July 6	Mean	2.9	0.23	0.99	0.16	2.2	0.45	9.3	111	68	17	27
	Median	2.9	0.24	1.0	0.16	2.7	0.47	9.9	110	67	17	20
	Range n = 5	2.6 - 3.1	0.15 - 0.28	0.72 - 1.4	0.15 - 0.19	0.95 - 3.0	0.31 - 0.54	4.9 - 13	60 - 170	46 - 81	12 - 22	14 - 43
Aug. 9	Mean	2.6	0.19	0.84	0.13	3.1	0.54	9.9	74	68	13	54
	Median	2.6	0.18	0.76	0.13	3.2	0.53	9.9	66	62	14	50
	Range n = 5	2.4 - 2.8	0.16 - 0.26	0.58 - 1.1	0.12 - 0.14	2.5 - 3.5	0.41 - 0.71	5.9 - 14	57 - 110	54 - 91	9 - 16	44 - 76
Sept. 2	Mean	2.5	0.18	0.82	0.12	2.7	0.49	5.7	87	52	10	41
	Median	2.5	0.17	0.82	0.12	2.7	0.49	6.7	82	45	12	36
	Range n = 5	2.2 - 2.6	0.13 - 0.23	0.62 - 1.0	0.11 - 0.13	2.3 - 3.2	0.37 - 0.63	2.3 - 6.9	72 - 110	39 - 78	5 - 14	34 - 62

a. % = % dry weight; ppm = parts per million.
b. n indicates the number of sites from which the data was obtained.

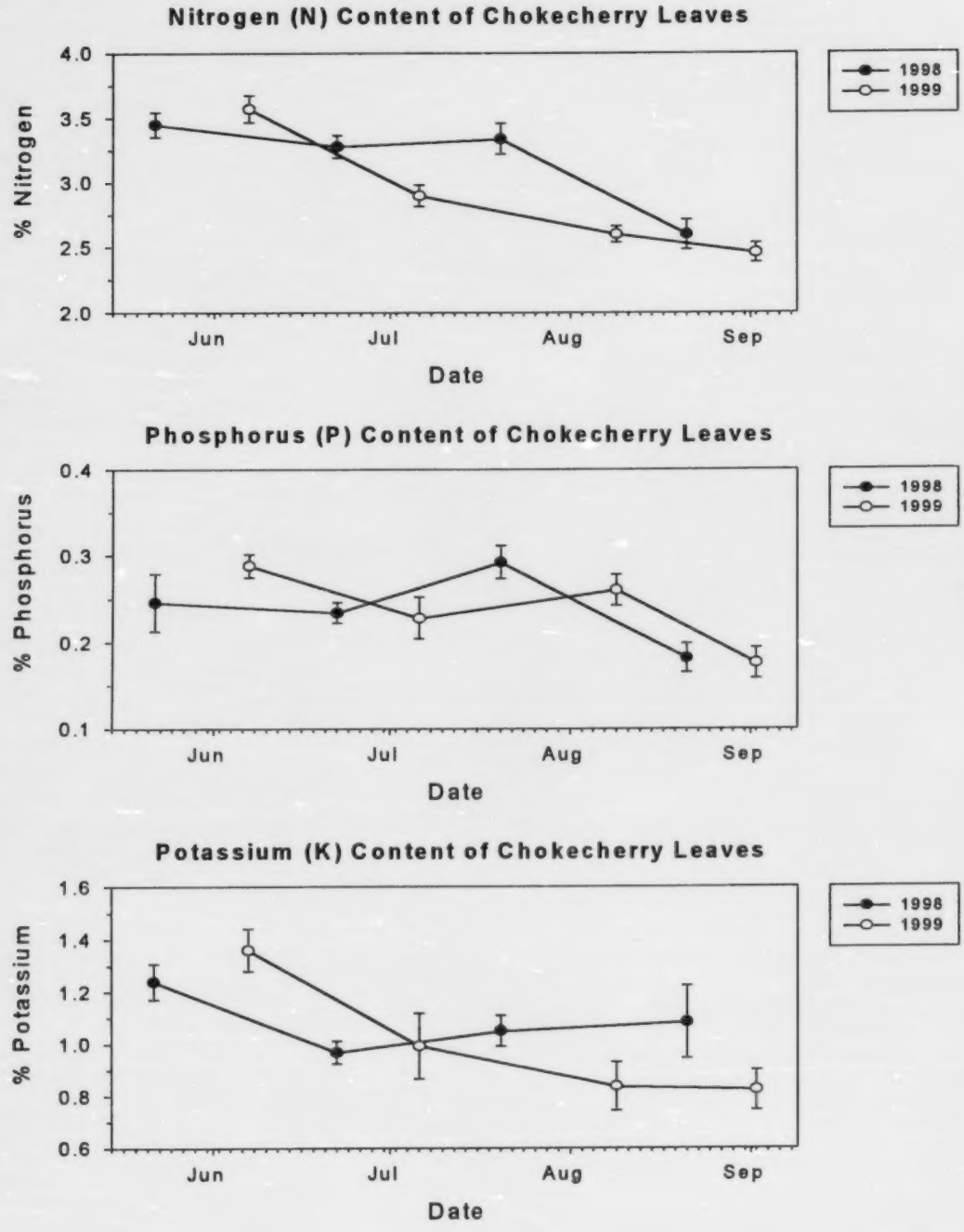


Figure 20. Nitrogen, phosphorus and potassium content of chokecherry leaves sampled by the University of Saskatchewan from May to September of 1998 and 1999. Five samples were collected from three sites for each date.

Greenhouse Fertilization Experiment - 1998

A fertilization experiment of potted saskatoon plants was conducted in the greenhouse to study the response of saskatoons to various fertilizer rates. One year old saskatoon plants of the cultivar Smoky were potted on Feb.11, 1998 in a soil mix of four parts topsoil, two parts perlite and one part turface in one gallon pots. The study consisted of a randomized complete block design of five fertilizer treatments, five replicates and four plants per experimental unit. Treatments consisted of 0, 100, 200, 300, 400 ppm 20-20-20 (0, 20, 40, 60 and 80 ppm N, $P_2 0_5$ and $K_2 0$) fertilizer applied with every watering commencing on Feb. 28. The composition of 20-20-20 fertilizer is shown in Table 20. This amount of fertilizer added to the pots was calculated to be the equivalent of adding approximately 348 kg N/ha (174 ppm) at the 400 ppm rate. The length of the current season's shoot growth was recorded every two weeks. Plants were harvested on May 21. Plant height, stem diameter, current season's shoot growth and the number of suckers were recorded. Leaf, stem, root and sucker fresh and dry weights were also taken. Soil and leaf samples from four of the five replicates were sent to Enviro-Test Laboratories for nutrient analysis. Data were analyzed using analysis of variance, contrasts, and Pearson correlations. The amount of nitrogen taken up by the plant was calculated by determining the amount of nitrogen already present in the soil, the amount added through fertilization, and the amount remaining in the soil at the end of the study.

Table 20. Nutrient content of Plant Products 20-20-20 fertilizer.

Element	Content (%)
Total Available Nitrogen (N)	20
Nitrate Nitrogen	5.90
Ammoniacal Nitrogen	3.85
Water Soluble Organic Nitrogen	10.25
Total Available Phosphoric Acid ($P_2 0_5$)	20
Soluble Potash ($K_2 0$)	20
Iron	0.100
Manganese	0.050
Zinc	0.050
Copper	0.050
Boron	0.020
Molybdenum	0.0005

Plant dry weights are presented in Figure 21. Root mass did not increase with an increase in fertilizer. Likewise, contrasts also revealed a significant linear relationship between fertilizer treatment and leaf, stem, sucker and total plant mass but not with that of roots. Stem diameter and the length of the current season's shoot growth were not significantly influenced by the fertilizer treatments, but the number of suckers significantly increased with the addition of fertilizer (Figure 22). Leaf and soil nitrogen, phosphorus, and potassium content, and plant

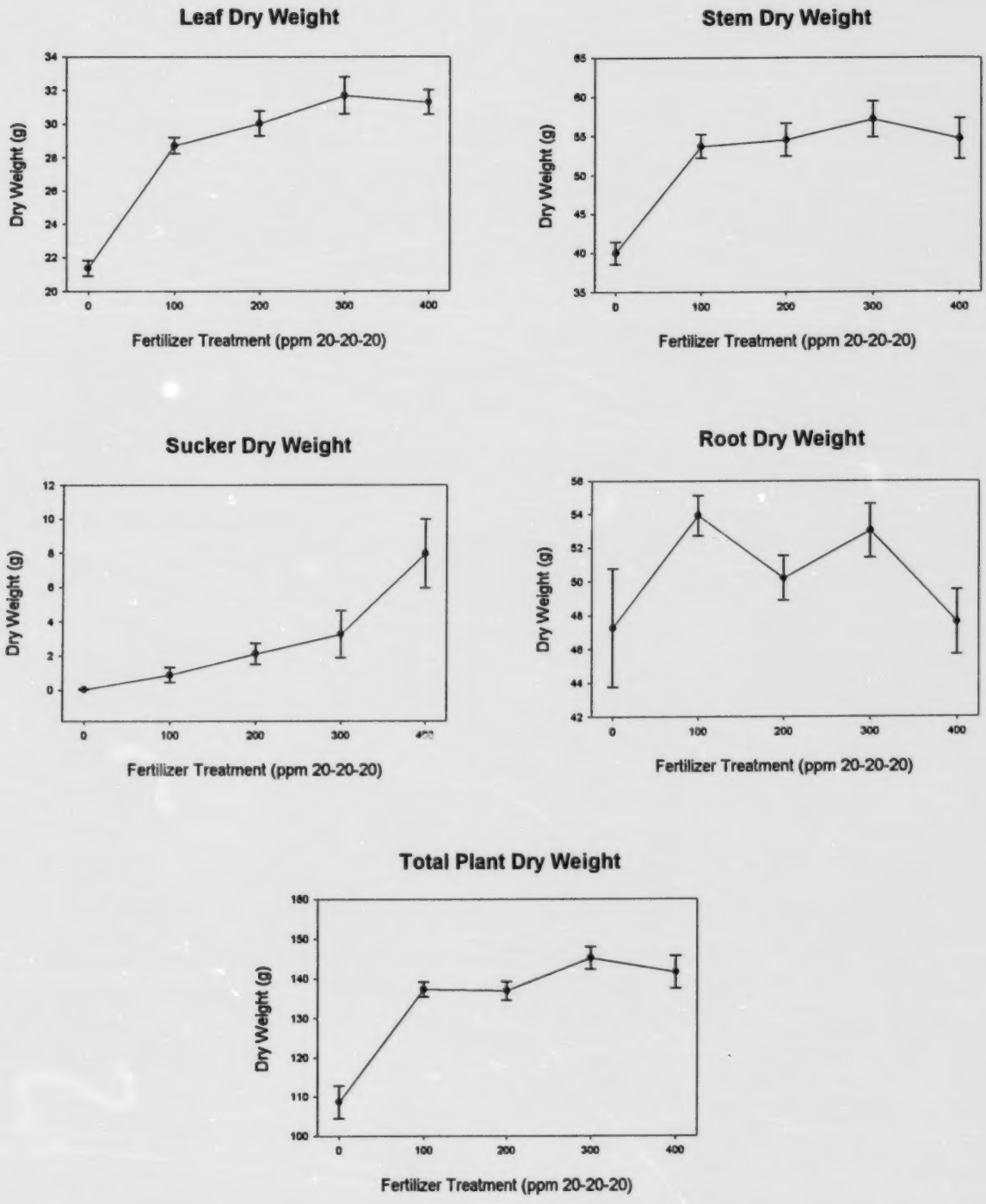


Figure 21. Growth response of potted saskatoon plants grown under five fertilizer regimes in the greenhouse in 1998. Growth is expressed as the dry weight of four plants.

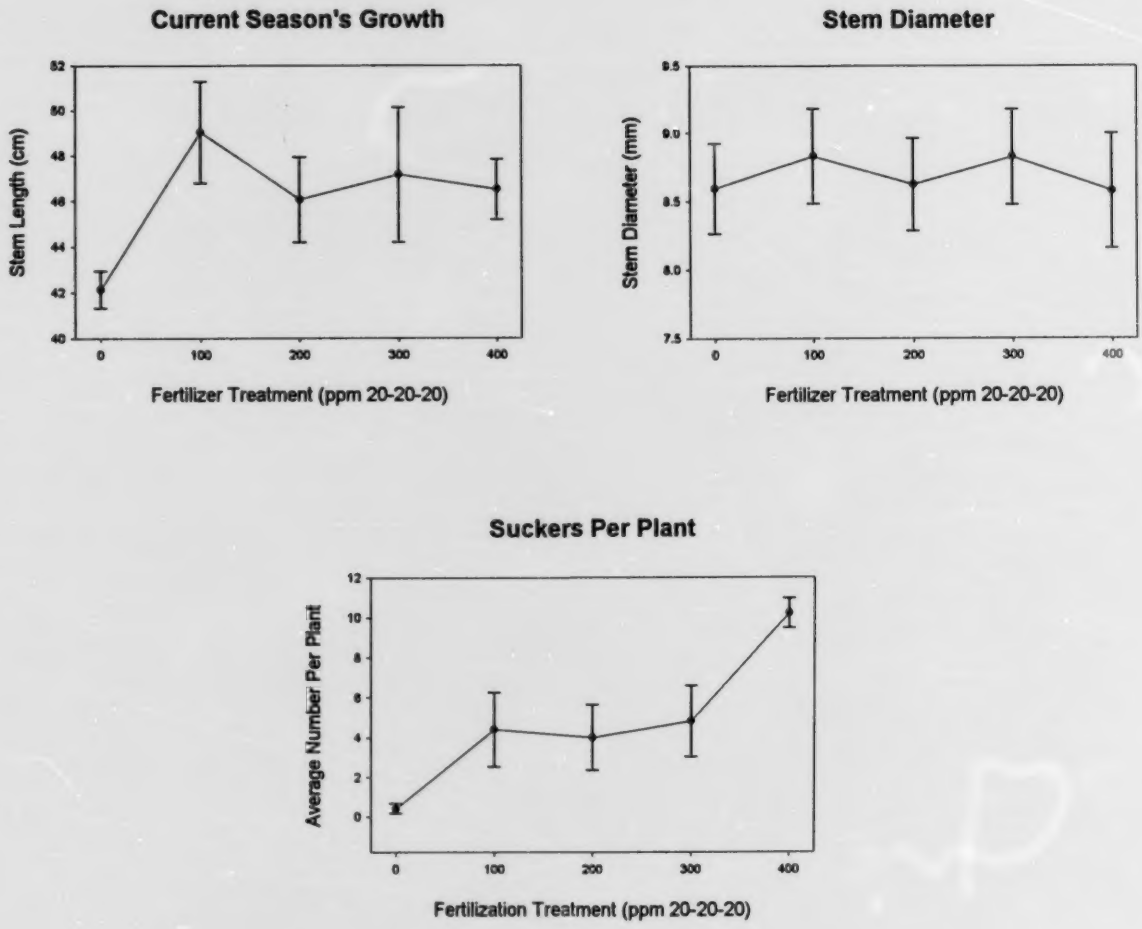


Figure 22. Growth response of potted saskatoon plants grown under five fertilizer regimes in the greenhouse in 1998. Growth is expressed as an average of four plants.

nitrogen uptake were all positively correlated with sucker number and the dry weights of the leaves, stems, suckers, and that of the entire plant. Some correlations also occurred between these measurements of plant growth and the remaining nutrients.

The fertilizer treatments significantly influenced all leaf nutrient levels except for zinc and copper (Figures 23 and 24). Contrasts revealed a significant linear relationship of foliar nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, manganese, and iron with fertilizer rate. Many of these nutrients also had significant quadratic and cubic effects in response to treatment which were likely the result of fluctuations in response, however, in all cases, the linear effect was the strongest. Boron showed a significant quadratic relationship with fertilizer rate, but not a linear one. Measurements of soil nitrate, phosphorus, potassium, iron, and manganese were positively correlated with that in foliar tissue. Plant nitrogen uptake was strongly correlated with leaf nitrogen content ($r=0.85$) (Figure 25).

Sulphur was not present in the fertilizer applied yet the plants responded with a greater uptake of sulphur in the fertilized pots. This is likely the result of the addition of other nutrients to the soil stimulating microbial activity, and thus, the break down of sulphur in the soil organic matter into more plant available forms. Calcium and magnesium were also not present in the fertilizer and yet their foliar levels increased in response to fertilizer application. The exact reason for this is not certain at this time particularly since soil levels of calcium and magnesium were not measured. This experiment will be repeated and soil calcium and magnesium analyzed to reveal their response in the soil.

In general, an increase in fertilizer in this study resulted in an increase in plant mass with the exception of the roots. This was particularly evident in the greater number of suckers produced by the plants at high fertilizer levels. This increase in vegetative growth is a well known response of plants towards high levels of nitrogen. Root mass appeared to be more influenced by the initial plant variability in vigour than to fertilizer. This lack of a significant response tends to suggest that sufficient phosphorus existed in the unfertilized pots for adequate root growth to occur. Root growth is promoted by high phosphorus levels relative to nitrogen. However, the fertilizer used in this study (20-20-20) does not have a high phosphorus to nitrogen ratio, thus, a more likely response to this fertilizer would be the promotion of vegetative top growth as opposed to root growth.

Fertilizer treatments produced significant increases in foliar nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, iron, and manganese. Foliar levels of copper, zinc and boron did not significantly increase with fertilizer application. This lack of increase could be a reflection of adequate levels of these nutrients existing at the start.

For the most part, there was little response in terms of plant growth to the addition of extra fertilizer beyond the rate of 100 ppm 20-20-20. This is not surprising as this rate would be equivalent to adding 87 kg N/ha. However, some leaching of the nutrients from the pots likely occurred as excess water drained from the pots. It should also be noted that the restricted soil

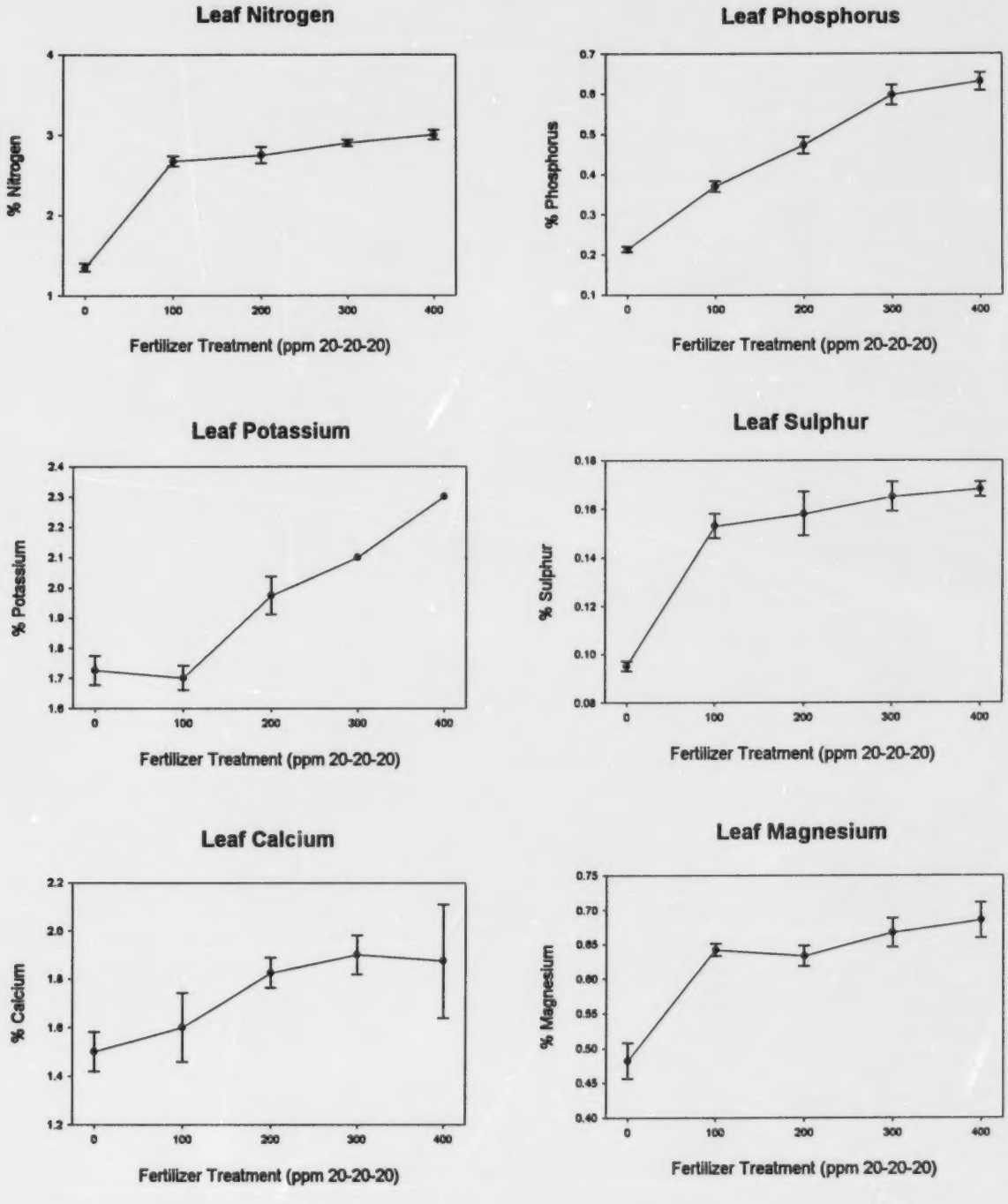


Figure 23. Leaf primary and secondary nutrient content of potted saskatoon plants grown under five fertilizer regimes in the greenhouse in 1998.

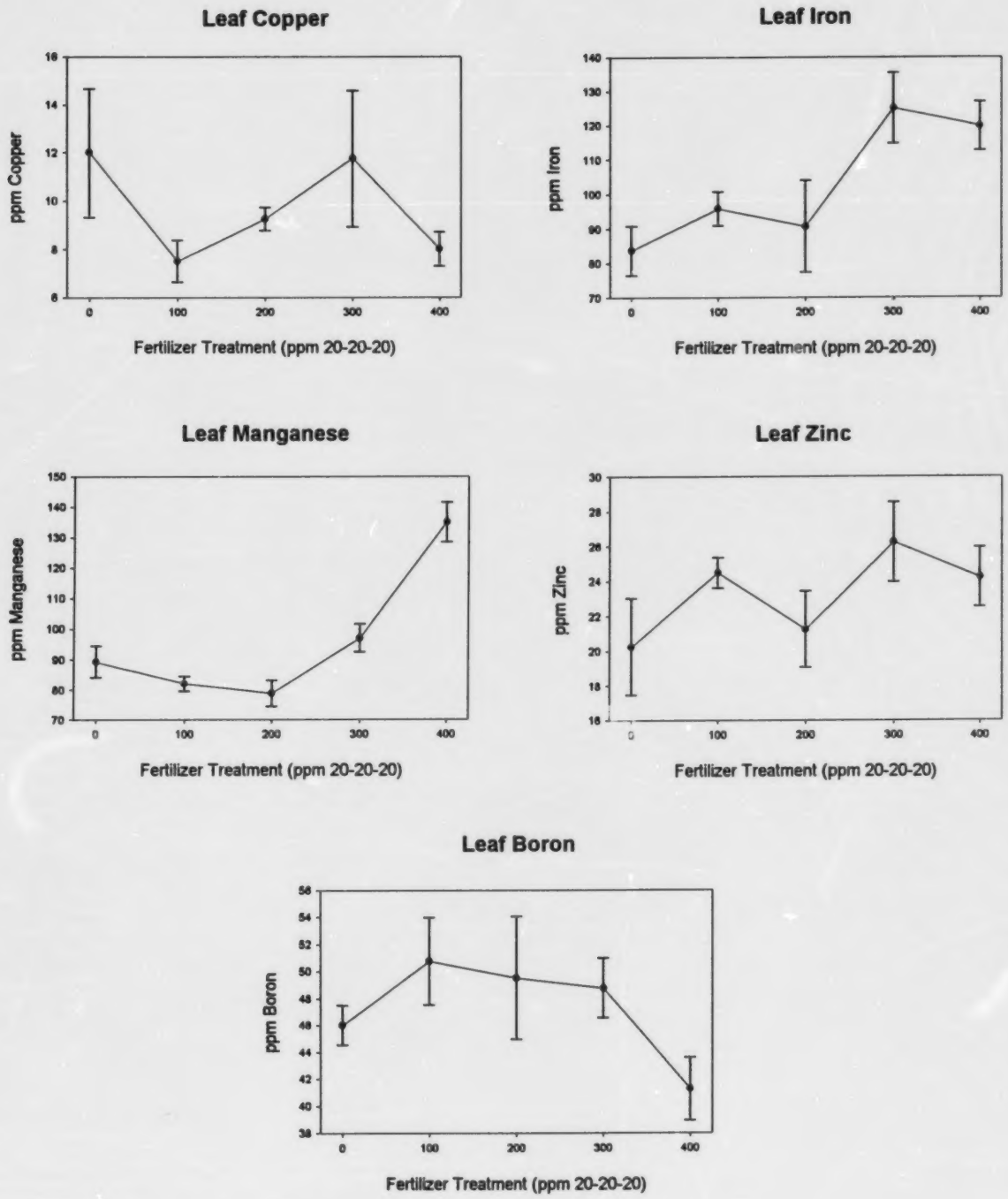
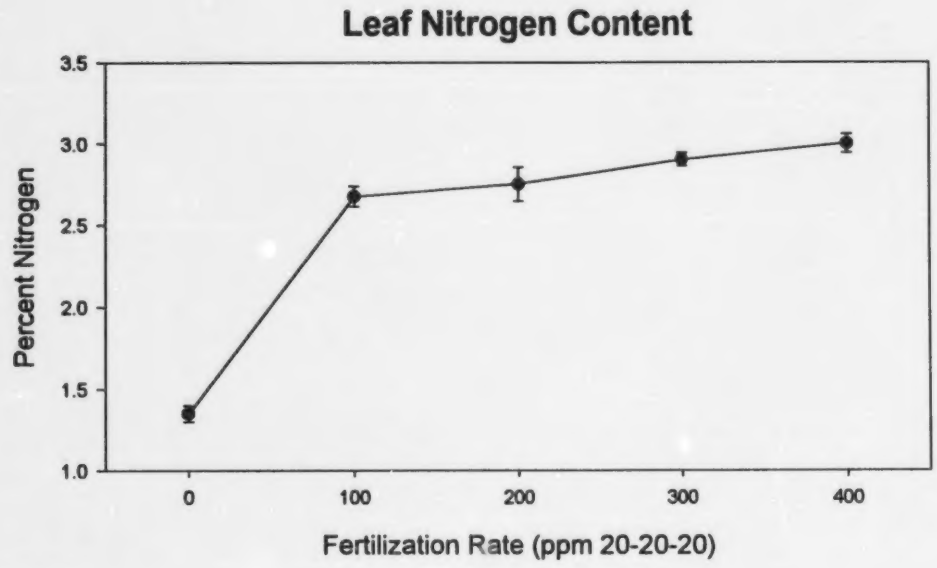


Figure 24. Leaf micronutrient content of potted saskatoon plants grown under five fertilizer regimes in the greenhouse in 1998.



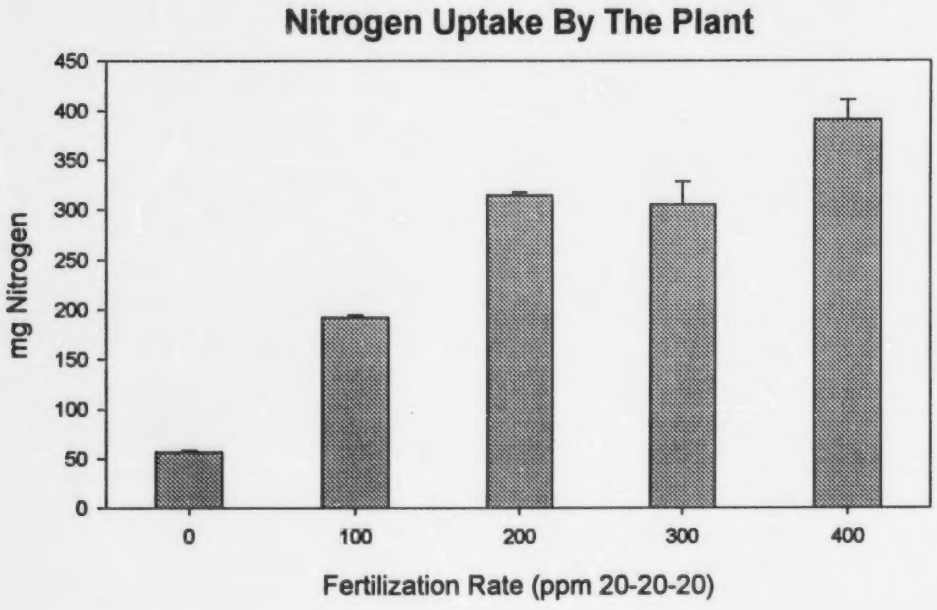


Figure 25. Leaf nitrogen content and soil nitrogen uptake of saskatoon plants grown under five fertilizer regimes in the greenhouse in 1998.

volume in the pots for the amount of roots would not occur in a field planted situation, and a much lower rate of fertilizer could be applied to the field to have the same effect on plant growth. These particular plants were quite large and vigorous compared to most plants in their second season.

At the 100 ppm rate, plants took up an average of 192 mg of nitrogen from the soil and their leaf nitrogen content was 2.68%. This percentage is within the normal range and slightly higher than the mean of leaf nitrogen levels in saskatoons as indicated by data of foliar analysis (Table 14). Plants grown at the 100 ppm rate had an average total plant dry weight of 32.4 g. Thus, these plants required 5.94 mg of N/g of dry matter.

Greenhouse Fertilization Experiment - 1999

The greenhouse fertilization experiment of potted saskatoon plants was repeated in 1999 with some alterations. One year old Smoky saskatoon plants were potted in a 1:1 mix of field soil and perlite, and placed in the greenhouse on Dec. 9, 1998. Leaching of nutrients in this experiment was prevented by placing saucers underneath the pots and by watering only until the water reached the bottom of the pot. Any excess water was caught in the saucer and eventually reabsorbed by the soil. In this manner, nutrient leaching was prevented thereby allowing a more accurate account of nutrient use by the plant. The experiment was set up as a randomized complete block with five treatments, five replicates and four plants per experimental unit. Fertilizer treatments were applied in the form of 20-20-20 at the following rates: 3.75, 7.5, 15, 30 and 60 ppm N, P_2O_5, K_2O (equivalent to 7.5, 15, 30, 60 and 120 kg N/ha). Fertilizer was applied in one application on Dec. 17. Initial and final plant height and basal stem diameter were recorded. Plants were harvested on March 24 and leaf, root, stem and sucker biomass were measured for both fresh and dry plant matter. Soil and leaf nutrient analysis was conducted at Enviro-Test Laboratories. Data were analyzed using analysis of variance, contrasts and Pearson correlations. The amount of nitrogen taken up by the plants were also calculated.

Leaf macro and micronutrient levels at the various fertilizer rates are shown in Figures 26 and 27. Contrasts revealed a significant linear relationship between fertilizer rate and levels of leaf nitrogen, potassium, sulphur, calcium, magnesium, manganese and zinc. However, this relationship was not always positive. Leaf nitrogen, sulphur, calcium, and magnesium increased with an increase in fertilizer, whereas, leaf potassium, manganese and zinc decreased. A few nutrients had significant correlations between leaf and soil. Leaf nitrogen and soil nitrogen levels were positively correlated ($r=0.87$). Significant correlations between leaf and soil potassium ($r=-0.46$), calcium ($r=-0.53$), magnesium ($r=-0.43$) and zinc ($r=-0.59$) were negative. Negative correlations between leaf and soil calcium and magnesium levels would be expected as these two nutrients were not supplied in the fertilizer and with an increase in fertilizer rate, any increase in general nutrient uptake and growth would also require greater amounts of calcium and magnesium from the soil. Potassium and zinc were negatively correlated between the leaves and soil because even though the soil content of these elements increased at higher fertilizer rates,

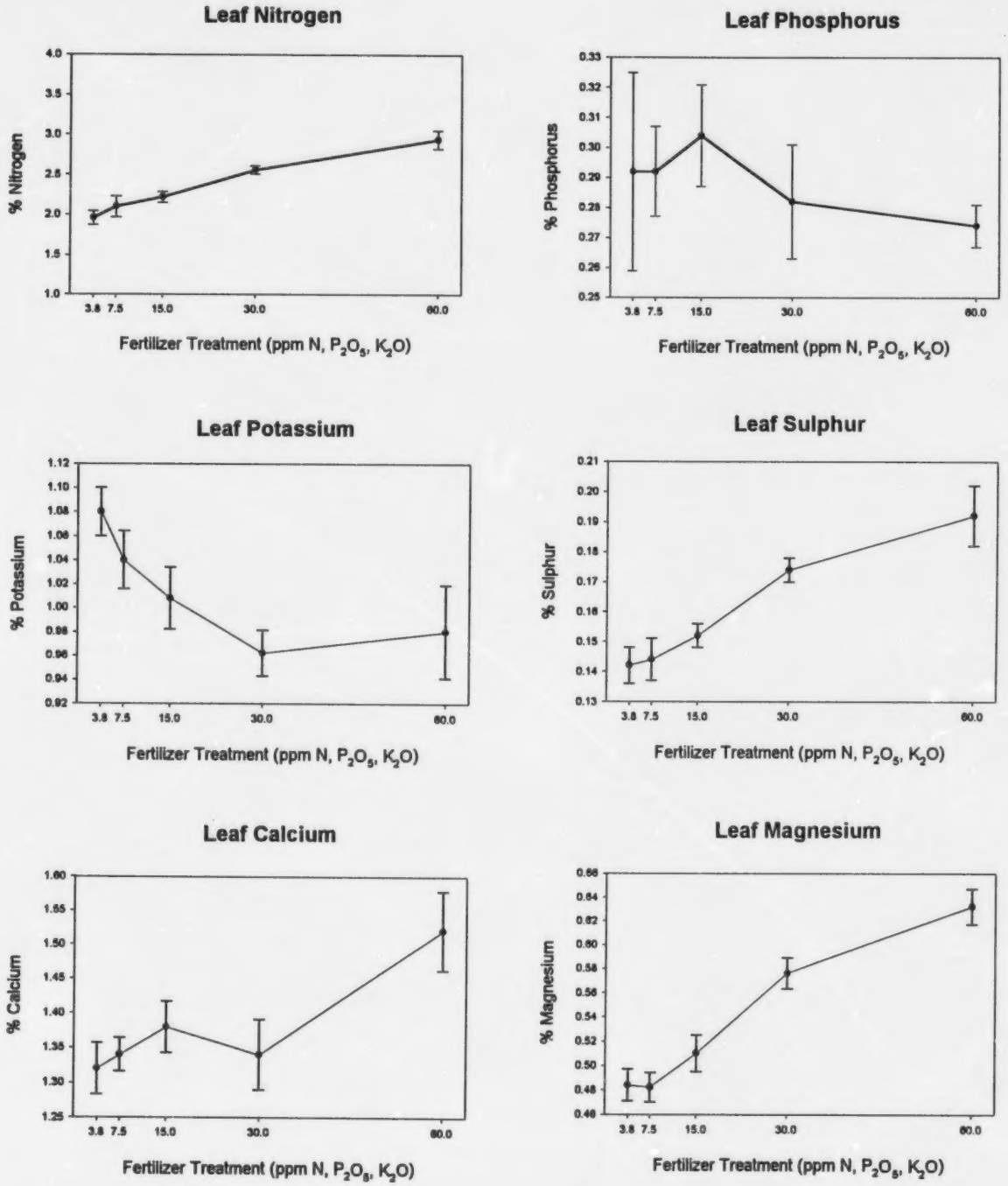


Figure 26. Leaf primary and secondary nutrient content of potted saskatoon plants grown under five fertilizer regimes of 20-20-20 in the greenhouse in 1999.

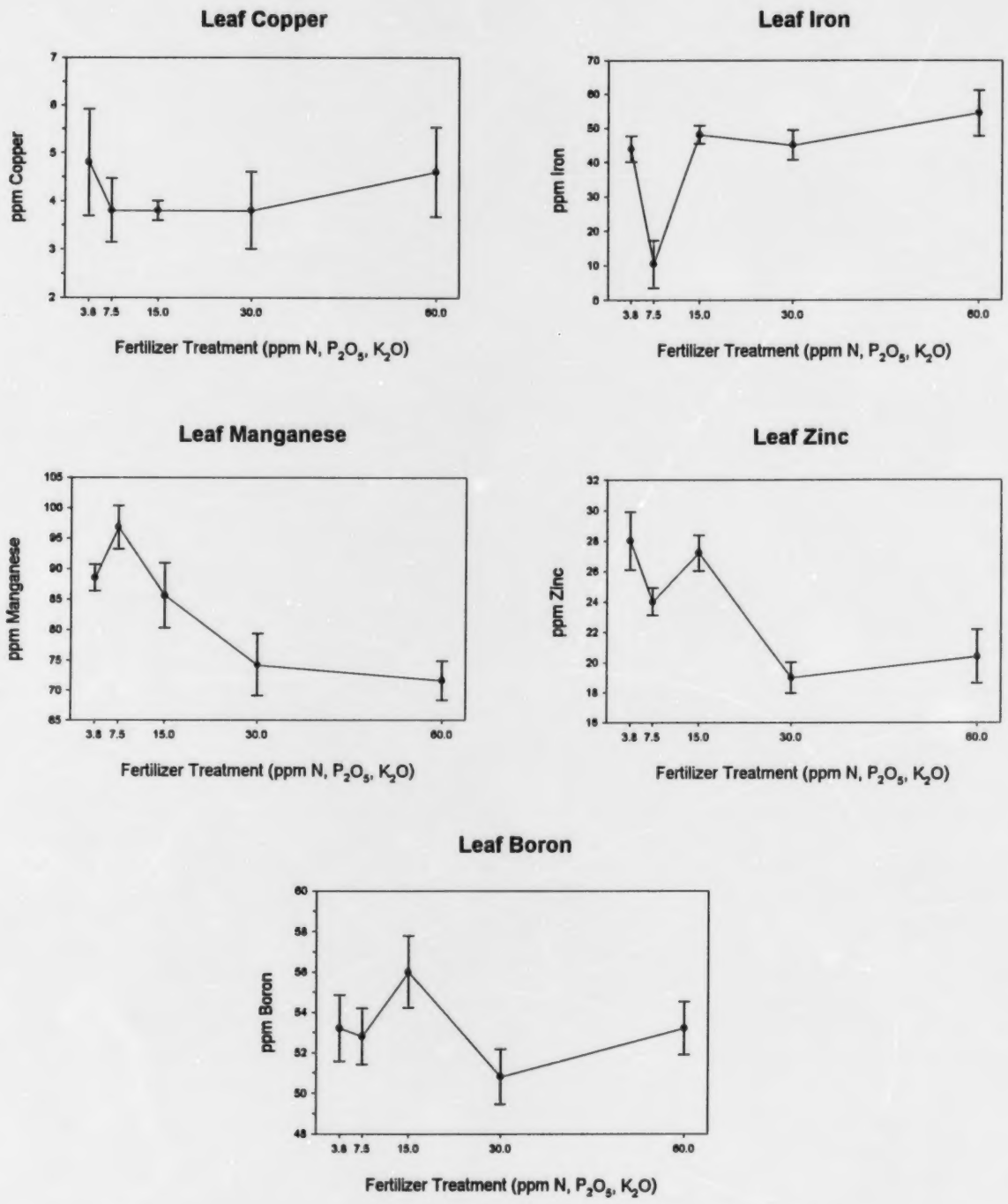


Figure 27. Leaf micronutrient content of potted saskatoon plants grown under five fertilizer regimes of 20-20-20 in the greenhouse in 1999.

leaf levels tended to decrease overall. It is not known why leaf potassium, manganese, and zinc decreased with an increase in fertilizer rate. Nitrogen uptake by the plant was strongly correlated with leaf nitrogen content (r=0.85) (Figure 28).

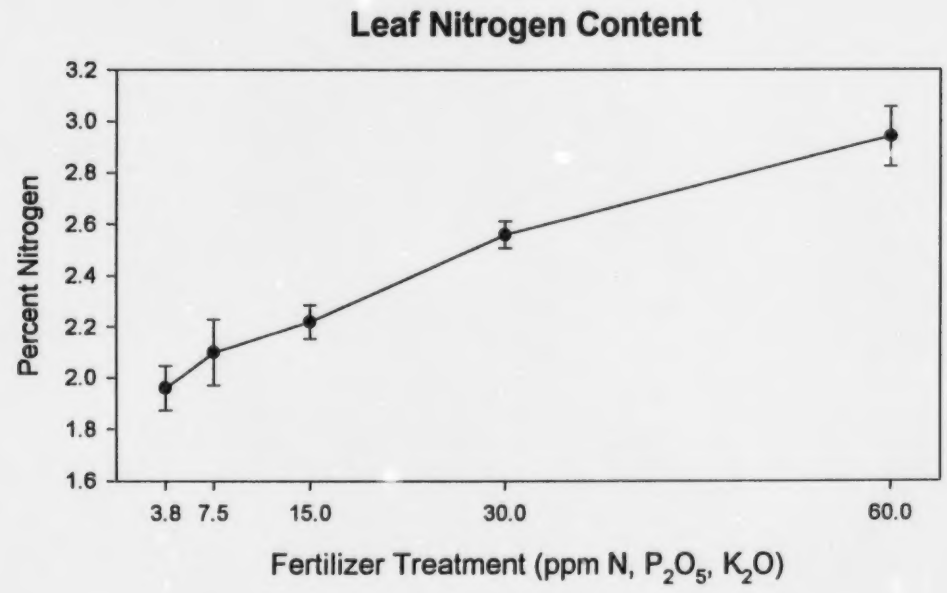
The number of suckers and sucker dry weight showed a positive linear increase to an increase in fertilizer (Figures 29 and 30). However, no other measures of growth were significantly different. Soil nitrogen and phosphorus content were positively correlated with sucker number (N: r=0.41; P: r=0.41) and sucker dry weight (N: r=0.43; P: r=0.43). Nitrogen uptake by the plant was also correlated with sucker number (r=0.48) and sucker dry weight (r=0.50). Very few significant correlations occurred between the various measures of growth and soil or leaf nutrient content. This suggests a general lack of relationship between growth and leaf or soil nutrient levels in this study. As growth was not significantly different among treatments except for suckering, this is not surprising.

The results from this study were not as dramatic as the previous greenhouse study using 20-20-20 fertilizer. However, the rates used in the first study were far greater. Plants used in the first study were larger and more vigorous, whereas the plants used in the second study were smaller and did not have the same vigorous growth as their chilling requirements were not totally satisfied. In addition, preventing leaching by the use of saucers occasionally created waterlogged conditions which would have a negative effect on plant growth and a reduction in nutrient uptake. These factors may have contributed to the reason why growth response in the second study was only evident in differences in suckering. Poor soil aeration reduces soil potassium uptake by the plant more than for other nutrients. This may have also had an effect on the poor uptake of potassium by the plant in the second study.

Based on leaf nitrogen content, soil nitrogen content between the 15 ppm and 30 ppm rates seemed to be adequate. The average leaf nitrogen content between these two rates was 2.39%. Mean nitrogen uptake by the plant between these two rates was 66 mg. Average plant dry weight of these two treatments was 13.1 g. Therefore, the plant required 5.1 mg of N/g of dry matter.

Nitrogen Fertilizer Outdoor Pot Experiment - 1998

An outdoor pot experiment was designed to enable the growing of larger trees for a number of seasons to examine the effect of nitrogen levels on flowering and fruiting of saskatoons. Plant Root Simulator (PRS™) probes were used to measure and monitor soil nutrients in the pots. These probes contain specially treated anion and cation exchange membranes that can trap ions from the soil, which can subsequently be extracted and measured. One advantage of using PRS probes is that they can measure soil nutrients by insertion of the probes in the soil without having to extract a soil core. This enables the periodic monitoring of soil nutrients in the pots without having to sacrifice soil or plants. PRS probes were obtained from and analyzed at Western Ag Innovations, Inc. (Saskatoon). At the end of the season, soil



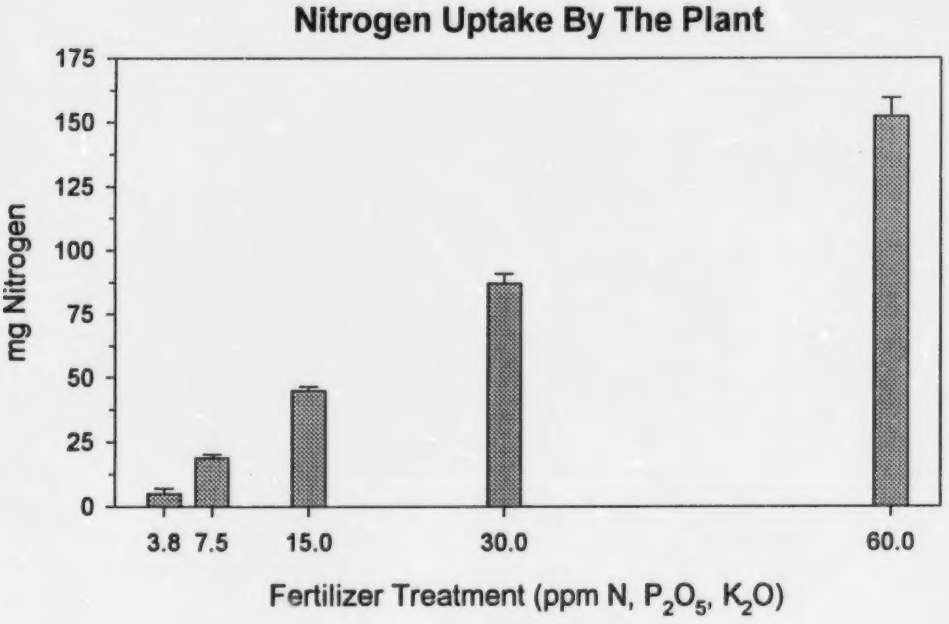


Figure 28. Leaf nitrogen content and nitrogen uptake of potted saskatoon plants grown under five fertilizer regimes of 20-20-20 in the greenhouse in 1999.

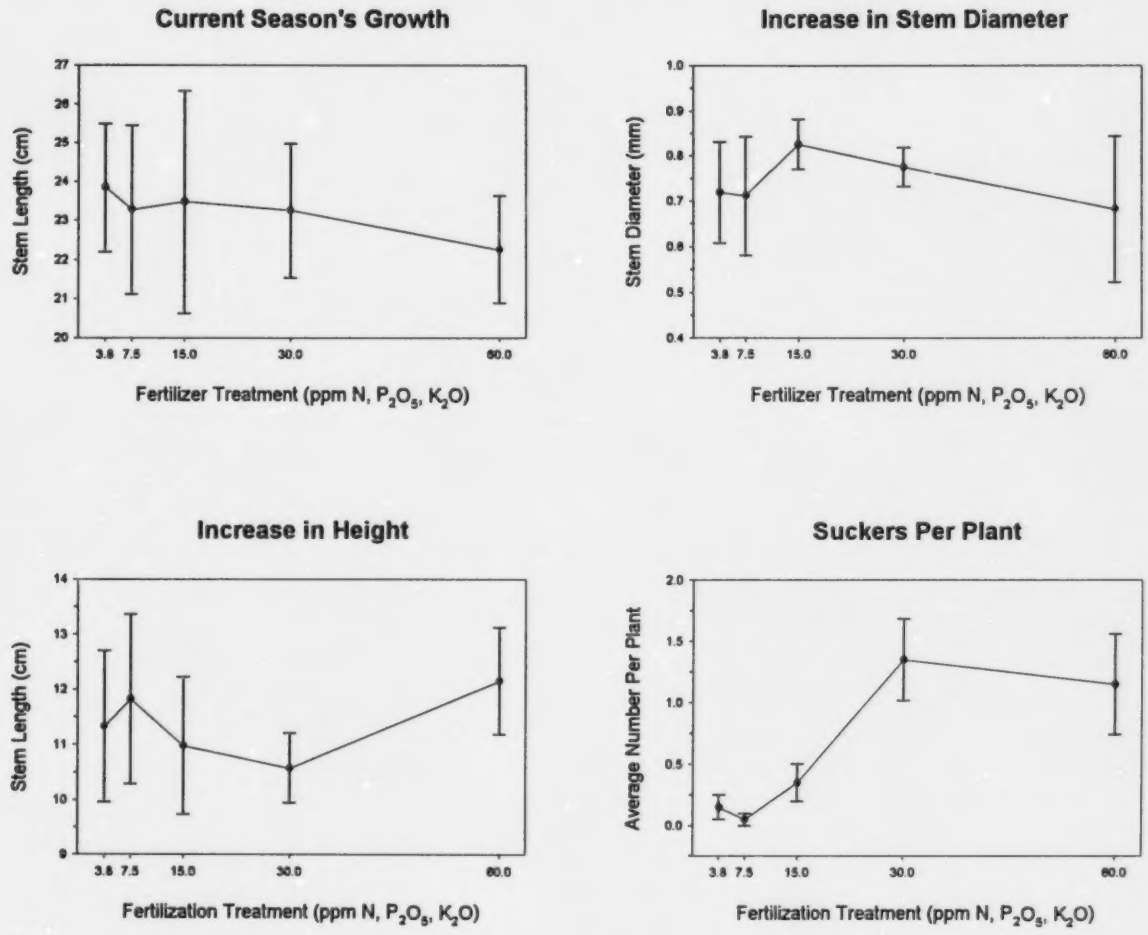

Current Season's Growth
Stem Length (cm)
Fertilizer Treatment (ppm N, P_2O_5, K_2O)
Increase in Stem Diameter
Stem Diameter (mm)
Fertilizer Treatment (ppm N, P_2O_5, K_2O)
Increase in Height
Stem Length (cm)
Fertilization Treatment (ppm N, P_2O_5, K_2O)
Suckers Per Plant
Average Number Per Plant
Fertilization Treatment (ppm N, P_2O_5, K_2O)

Figure 29. Growth response of potted saskatoon plants grown under five fertilizer regimes of 20-20-20 in the greenhouse in 1999. Growth is expressed as an average of four plants.

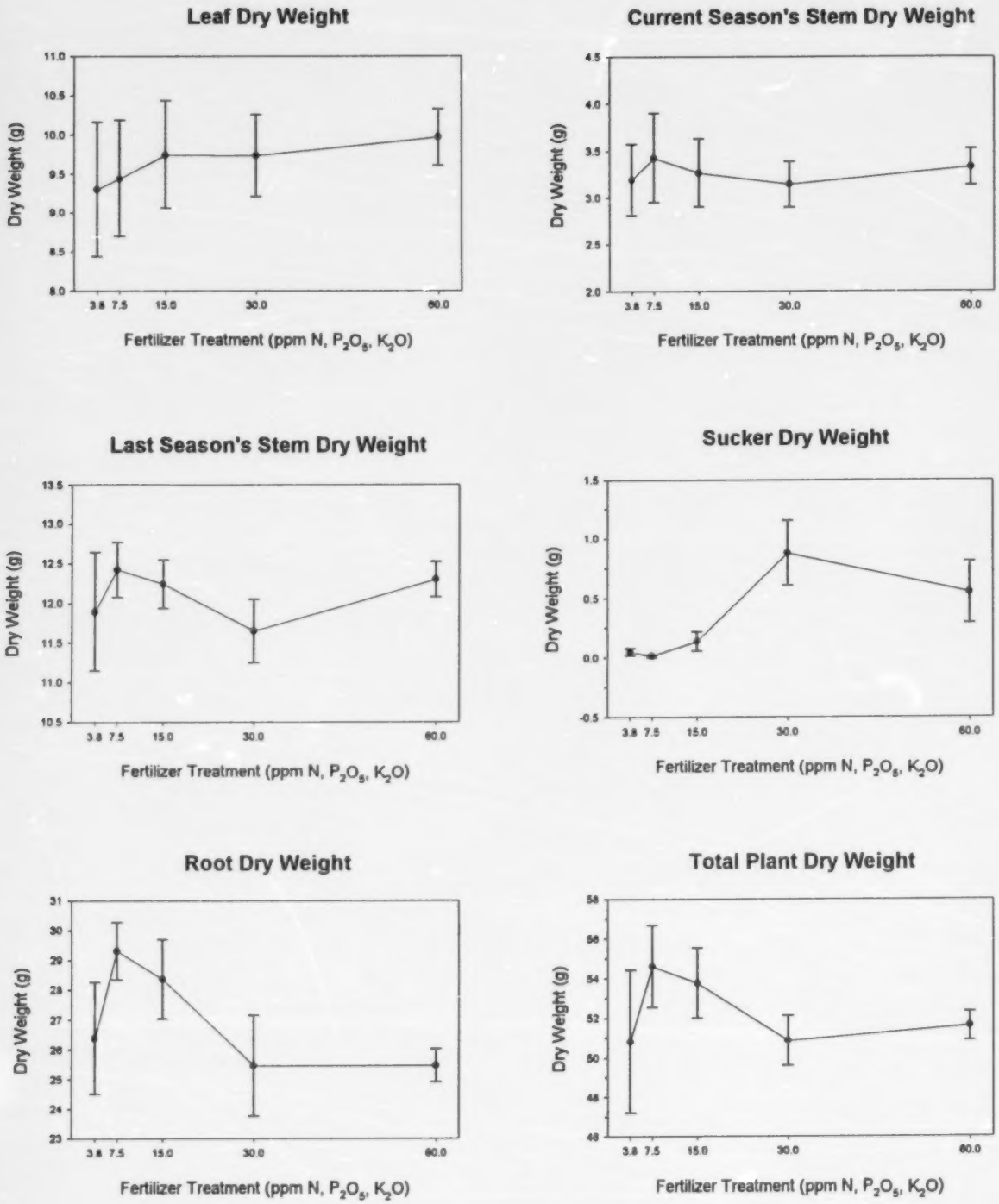


Figure 30. Growth response of potted saskatoon plants grown under five fertilizer regimes of 20-20-20 in the greenhouse in 1999. Growth is expressed as the dry weight of four plants.

was also analyzed using the traditional extraction method at Enviro-Test Laboratories (ETL) to enable a comparison with results found using the PRS probes.

This study consisted of three fertilizer treatments (0, 25 and 50 ppm nitrogen), four replicates, and eight potted plants per experimental unit in a randomized complete block design. Nitrogen fertilizer was applied in the form of urea (46-0-0). This project was designed so that at the end of each growing season one plant per experimental unit would be harvested, biomass and growth measurements taken, and foliar and soil nutrients measured. However, this year's study was terminated due to plant damage from feeding deer. Our plans were to repeat this experiment commencing with the first growing season in the greenhouse after which plants would be given a dormant period in cold storage for four months and then grown for another season, thereby permitting two growing seasons in one year.

Materials and Methods

One year old Smoky saskatoon plants were potted on May 14 and 15 in a soil mix of 3:2 topsoil:perlite in 15 L pots. The topsoil was a clay soil obtained from the University of Saskatchewan Horticulture Research plots in Saskatoon. Soil samples were sent to ETL for nutrient analysis at the time of potting.

Fertilizer application: Fertilizer treatments were 0, 25 and 50 ppm nitrogen applied using granular urea fertilizer. Fertilizer concentration was based on medium weight in a pot (1.07 g urea/pot for 50 ppm and 0.535 g urea/pot for 25 ppm). Granular urea (46-0-0) was ground and dissolved in deionized water and made to a certain concentration so that 10 mls of this concentrate was added to each pot to obtain the correct fertilizer rate. Fertilizer was applied to pots on June 24 in which 10 mls of concentrate was mixed with approximately 1.5 L of water for each pot. Just water was added to the controls. This amount of water was enough to distribute the fertilizer throughout the pot without leaching out. Fertilizer was applied again at the same rate on July 22 to replace nutrient loss due to leaching.

Probe measurements: One pot per experimental unit was selected for soil nitrate measurements using PRS probes. Probes were inserted into pots and deionized water was added around the probes to ensure sufficient moisture to bring the soil to field capacity. Probes were removed 24 hours later and taken to Ag Western Innovations for analysis. Nitrate measurements using probes were conducted on the following dates: June 18 (prior to fertilizer application), June 25 (after first fertilizer application), July 24 (after second fertilizer application) and Aug. 24 (at the termination of the experiment).

Harvest: On August 26 (Reps 1 to 3) and August 27 (Rep 4) the plants were harvested. Growth measurements included stem diameter, total height, the length of the current season's growth, and number of suckers. Biomass of foliage, stem tissue, roots and suckers was measured on both fresh and dry weights. Tissue was dried at 60°C from Aug. 27 to Aug. 31. At the time of harvest, soil was sampled from each selected pot for probe measurements within an experimental

unit. Soil samples and dried leaf samples were sent to Enviro-Test Laboratories for both macro- and micro-nutrient analysis.

Data Analysis: All soil and foliar nutrients, and growth and biomass measurements were analyzed by analysis of variance and linear contrasts. Correlations were also done between soil nitrogen measured on the various dates with foliar nitrogen. Results between the different soil analyses (PRS probes and ETL) were also compared using correlation analysis. Soil and leaf nitrogen contents were compared with growth and biomass measurements using correlations.

Results

Soil and foliar nutrients (Figure 31): Fertilized plants had significantly higher leaf nitrogen content than unfertilized plants at harvest. A significant linear relationship existed among the fertilization treatments for leaf nitrogen. Soil nitrate content on June 19 prior to fertilizer application did not significantly differ among treatments as would be expected. Nitrate content measured on all other dates differed significantly among treatments and showed a significant linear increase in response to an increase in fertilizer rate. On June 26, fertilized pots had higher nitrate levels than the unfertilized. All treatments had significantly different nitrate levels from each other on July 25. On August 25, pots treated with 50 ppm N had significantly higher nitrate content than the other two treatments which did not differ from each other. Final soil nitrate content measured at Enviro-Test Laboratiories showed both fertilizer treatments to have significantly higher nitrate content than the unfertilized pots. Leaf nitrogen was significantly correlated with soil nitrate on June 26 ($r=0.63$) and on July 25 ($r=0.68$). ETL test for soil nitrate was closely correlated with that of probes on all dates following fertilization treatment ($r=0.91$, 0.93 and 0.94 for June 26, July 25, and August 25 respectively).

Growth measurements (Figure 32): The number of suckers among treatments at the time of harvest differed significantly with a greater number of suckers being produced by fertilized plants. Linear effects were also significant for sucker number indicating an increase in suckering with an increase in nitrogen. Stem diameter, total plant height and the length of the current season's shoot growth were not significantly different among treatments. Sucker number was significantly correlated with soil nitrate levels on June 26 ($r=0.59$), and with leaf nitrogen content ($r=0.69$). No other growth measurements were correlated with nitrogen content except for the length of the current season's shoot growth which was negatively correlated with leaf nitrogen content ($r=-0.63$).

Biomass (Figure 33): Fertilized plants had significantly higher sucker dry weights than unfertilized. Linear contrasts also showed sucker dry weight to be significantly affected by treatment. Leaf, stem and root dry weights did not differ significantly among treatments. Sucker dry weight was correlated with soil nitrate content after fertilizer application on June 26 ($r=0.82$), July 25 ($r=0.81$) and at harvest as assessed by ETL ($r=0.71$). Leaf nitrogen content was correlated with sucker dry weight ($r=0.80$), root dry weight ($r=0.64$), total top growth dry weight ($r=0.61$), and total plant dry weight ($r=0.63$).

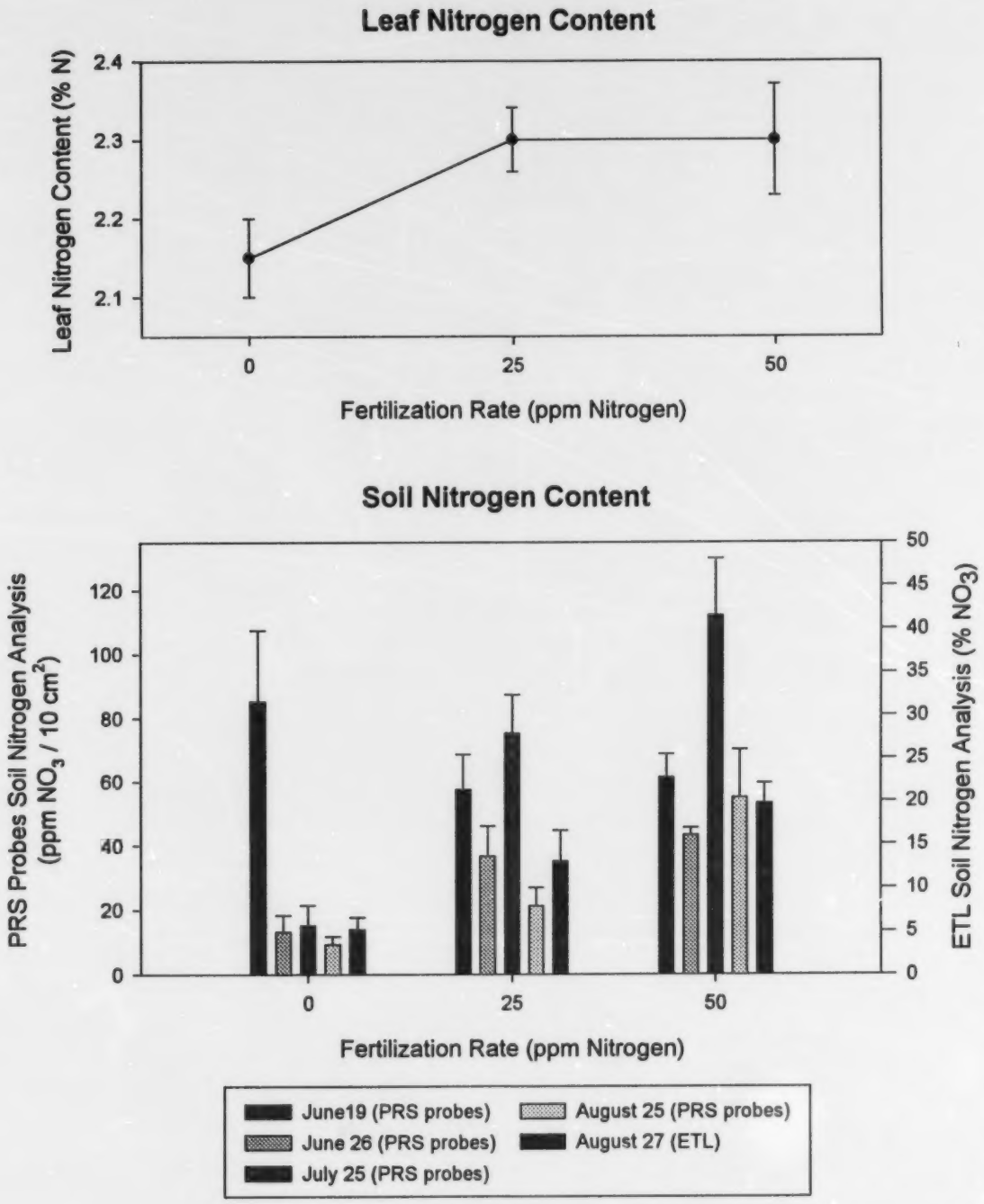


Figure 31. Soil and leaf nitrogen levels of potted saskatoon plants grown outdoors at three different fertilizer rates in 1998.

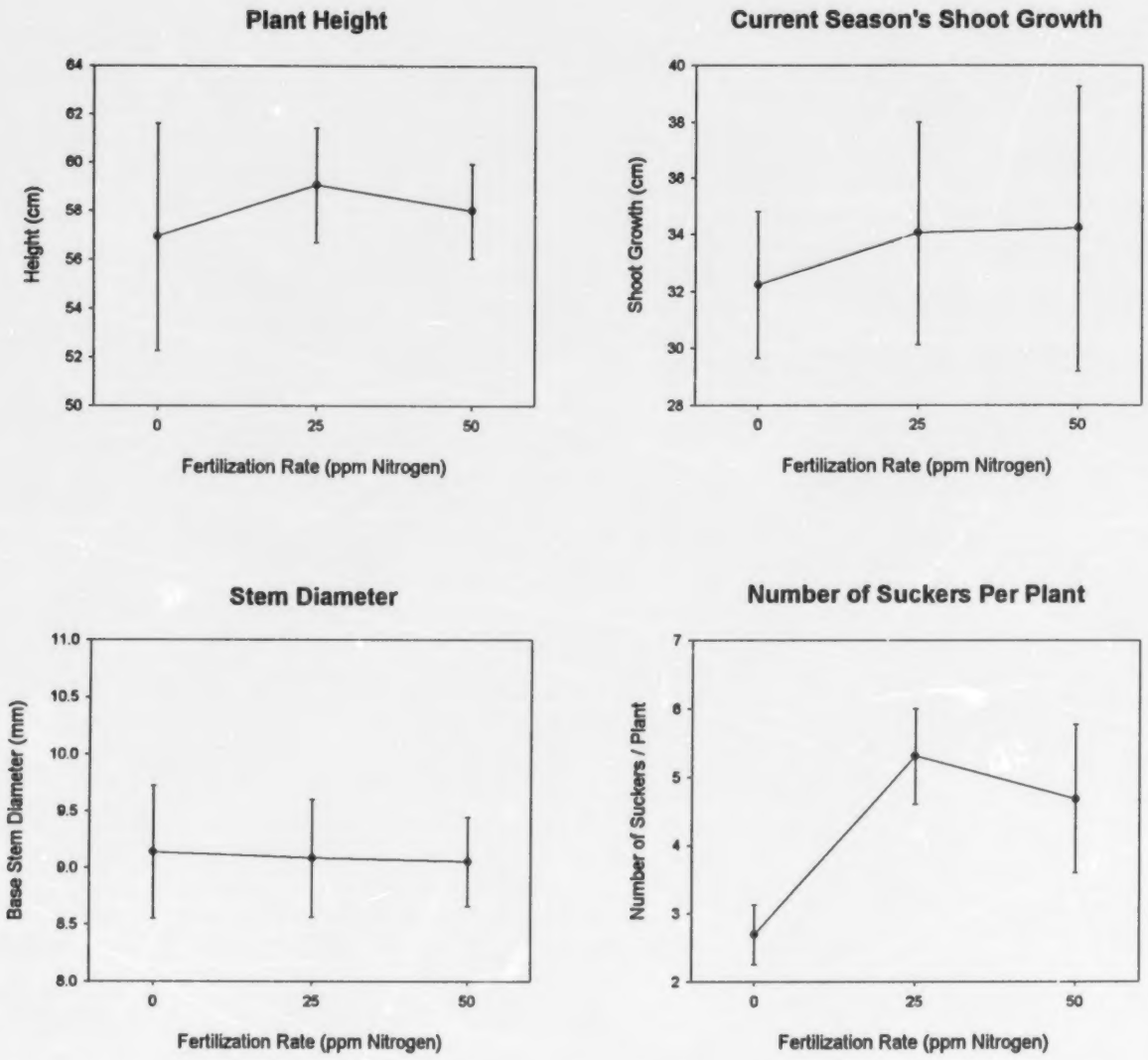


Figure 32. Growth response of potted saskatoon plants grown outdoors in 1998 at three different fertilizer rates. Growth is expressed as an average of 8 plants.

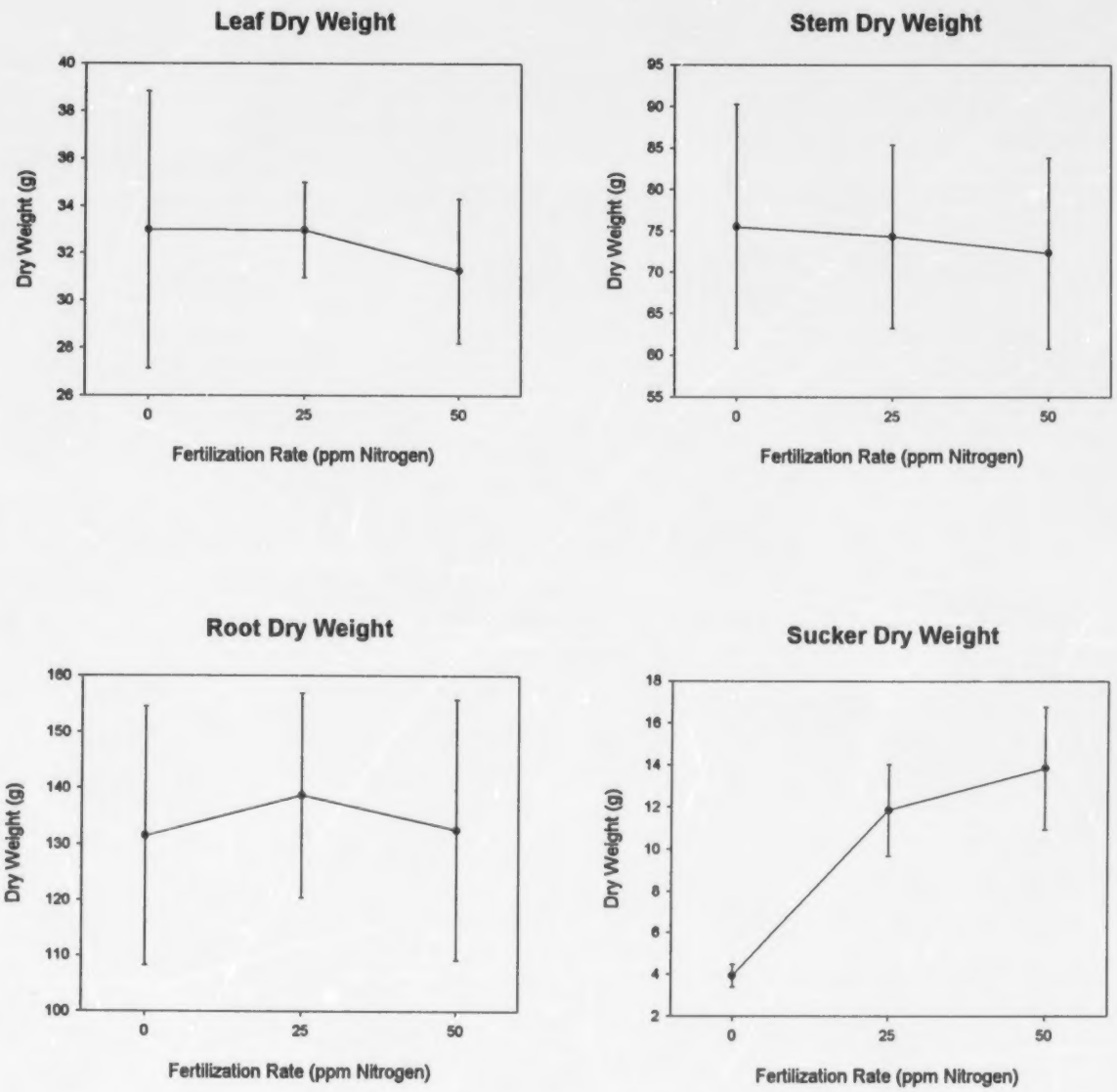


Figure 33. Growth response of potted saskatoon plants grown outdoors in 1998 at three different fertilizer rates. Growth is expressed as percent dry weight of 8 plants.

Discussion and Conclusions

In this study, the application of fertilizer did increase leaf nitrogen content, and sucker growth. In general there was no extra response at 50 ppm over that at the 25 ppm rate indicating that enough nitrogen was likely available for growth at the lower rate. This was also evident in the leaf nitrogen content which was sufficient at the 25 ppm rate (2.3%) and did not increase any further at the 50 pm rate. This is not surprising since 50 ppm nitrogen applied twice is approximately equivalent to adding 90 kg N/ha. However, it is also not known how much of this nitrogen was lost due to leaching which would not have occurred in a field situation to the same degree. It should also be noted that if it were not for the leaching of nitrogen from the unfertilized pots, there may have been sufficient nitrogen already present in the soil for optimum growth without the addition of fertilizer particularly since the soil mix had an adequate level of nitrogen at the time of potting (PRS probe average of 86.8 ppm NO_3/10 cm^2).

Correlation analysis indicated that as leaf nitrogen increased, sucker growth increased, current season's shoot growth decreased and root growth increased. Although the current season's shoot growth appeared to decrease with an increase in leaf nitrogen, this measurement is somewhat unreliable due to shoot damage from deer. As well, only the longest current season's shoot was measured. If more branching occurred at a higher nitrogen rate then the measure of the longest current season's shoot growth would not be representative of the plant because the effect of branching is such that the plant must spread its energy among a number of shoots resulting in shorter but more growth than if only one primary shoot existed. Overall total top growth and total plant biomass increased when leaf nitrogen increased. It must be noted that although significant correlations existed between leaf nitrogen and current season's shoot growth and root dry weight, they were not strong correlations, and that current season's shoot growth, total top growth, root dry weight, and total plant biomass were not significantly influenced by fertilizer treatment. Nitrogen is known to promote vegetative growth. In the saskatoon, this response was seen as the promotion of sucker growth in preference to additional shoot growth.

Soil nitrate analysis from PRS probes and from Enviro-Test Laboratories were very closely correlated, suggesting the two methods of nitrate extraction are comparable.

Nitrogen Fertilizer Pot Experiment - 1999

The nitrogen fertilizer pot experiment was repeated in 1999 in the greenhouse with some changes incorporated. Saucers were used at the bottom of the pots and watering was regulated in order to prevent nutrient leaching. As well, an additional treatment was added to the 1999 study. The experiment was set up as an randomized complete block design with four replicates, four treatments and six plants per experimental unit. This study continued for two growing seasons, in which half the plants were harvested at the end of each season. Two year old Smoky saskatoon plants were potted in 1:1 soil and perlite mix and placed in the greenhouse on Dec. 9, 1998. Soil nitrate content was measured using PRS probes on Dec. 16. Fertilizer was applied to pots on

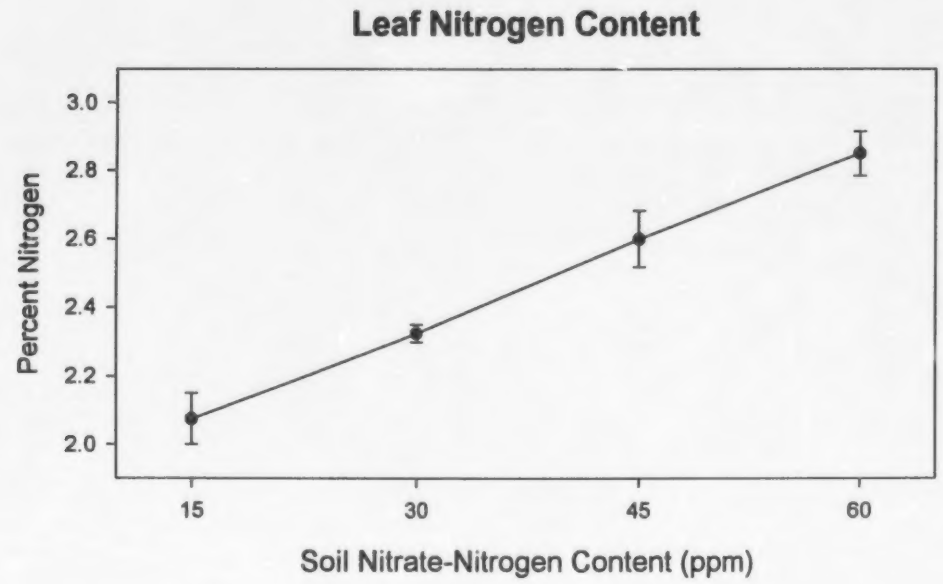
Dec. 23 at the following rates: 30, 60, 90 and 120 kg N/ha. Fertilizer was applied as 20-20-20 to all the pots at a rate of 30 kg N/ha, and as urea (46-0-0) to make up the additional nitrogen for the 60, 90 and 120 kg N/ha treatments. Extra phosphorus was added to each pot to bring the total soil phosphorus content up to 60 kg P/ha. Probe measurements were also taken on Dec. 27, Jan. 26, Mar. 1, and Mar. 25, by inserting one probe into each pot for 24 hours. Half of the plants were harvested on Mar. 29 and leaf, root, stem and sucker biomass were measured. Initial and final plant height and basal stem diameter were recorded. Soil nitrate and leaf nitrogen analysis was also done at Enviro-Test Laboratories. The remainder of the plants were placed in a growth chamber to acclimate them into dormancy after which they were kept in a cooler at 2°C to meet their chilling requirements. Plants were removed from the cooler on Oct. 1 and grown in the greenhouse to continue the study for another season. According to the soil test at the end of the previous growing season, the nitrogen fertilizer required to bring soil nitrogen content back up to the original treatment levels was calculated and pots fertilized on Oct. 14. Soil probes were inserted on Oct. 20. However, due to difficulties in achieving good contact between the soil and the probe, the use of soil probes were discontinued in this study. The plants were harvested on Dec. 21. Growth measurements of stem diameter, the length of the current season's growth and number of suckers were recorded. Plant biomass of leaves, stems, roots and suckers were also measured. Data from both growing seasons were analyzed using analysis of variance, contrasts and Pearson correlations.

Results of first growing season

A strong positive linear relationship existed between soil nitrogen treatments and leaf nitrogen levels (Figure 34). The amount of nitrogen taken up by the plants were strongly correlated with leaf nitrogen content (r=0.92). Soil nitrate content was also positively correlated with leaf nitrogen content at the end of the season (r=0.78). A significantly greater number of suckers were produced by plants at the highest rate of nitrogen (Figure 35). Stem diameter also showed a significant linear increase with an increase in soil nitrogen. However, an increase in soil nitrogen did not result in any significant increase in plant biomass (Figure 36). Plant nitrogen uptake was correlated with the increase in stem diameter (r=0.65).

Results of second growing season

Leaf nitrogen levels increased in a significant linear fashion in response to soil nitrogen treatments (Figure 37). Nitrogen uptake by the plant was strongly correlated with leaf nitrogen content (r=0.94). Growth differed significantly in response to nitrogen treatments during the second growing season (Figures 38 and 39). The length of the current season's stem growth, the increase in stem diameter, and the dry weights of the roots, older stem, total stem and the total plant all increased in a linear fashion in response to nitrogen treatments. The dry weight of the current season's stem growth was significantly lower at the 15 ppm rate than at the average of the three higher rates. The increase in stem diameter and the length of the shoot growth over the last two seasons both had a significant positive linear response to nitrogen treatments (Figure 40). Leaf nitrogen content and plant nitrogen uptake was positively correlated with root dry weight



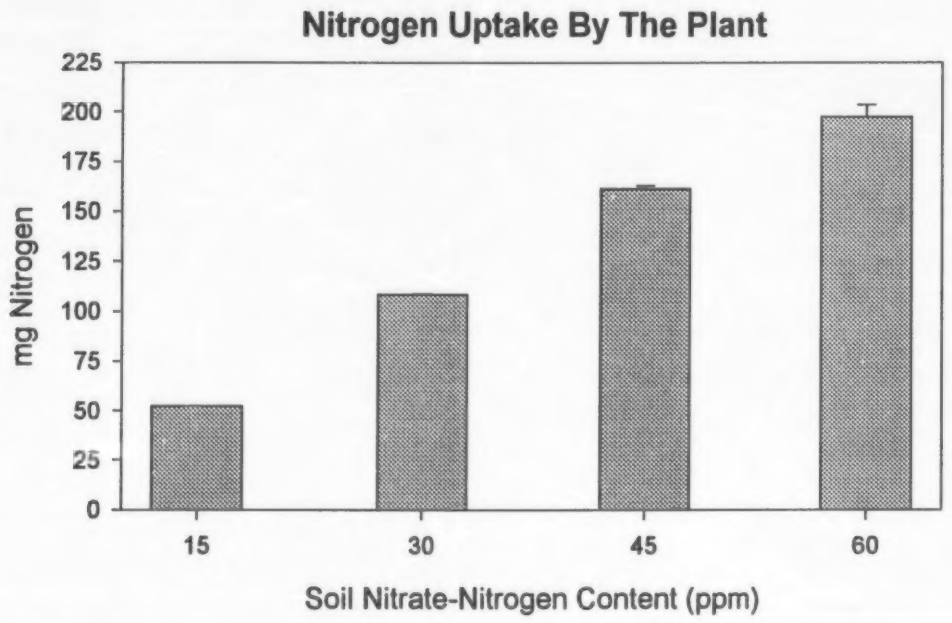


Figure 34. Leaf nitrogen content and nitrogen uptake of potted saskatoon plants grown in the greenhouse in 1998-99 at four different soil nitrogen levels.

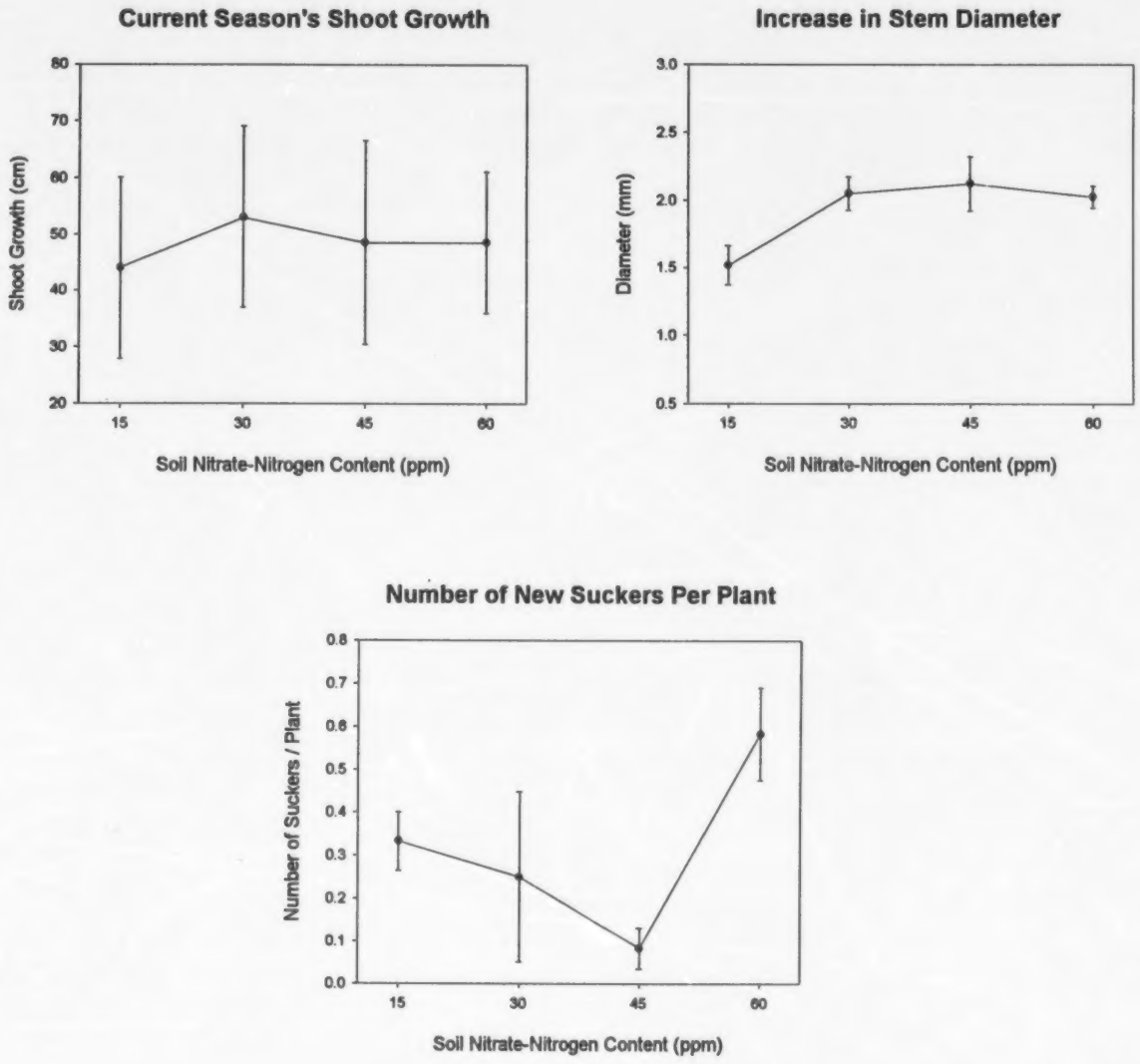


Figure 35. Growth response of potted saskatoon plants grown in the greenhouse in 1998 at four different soil nitrogen levels. Growth is expressed as an average of 3 plants.

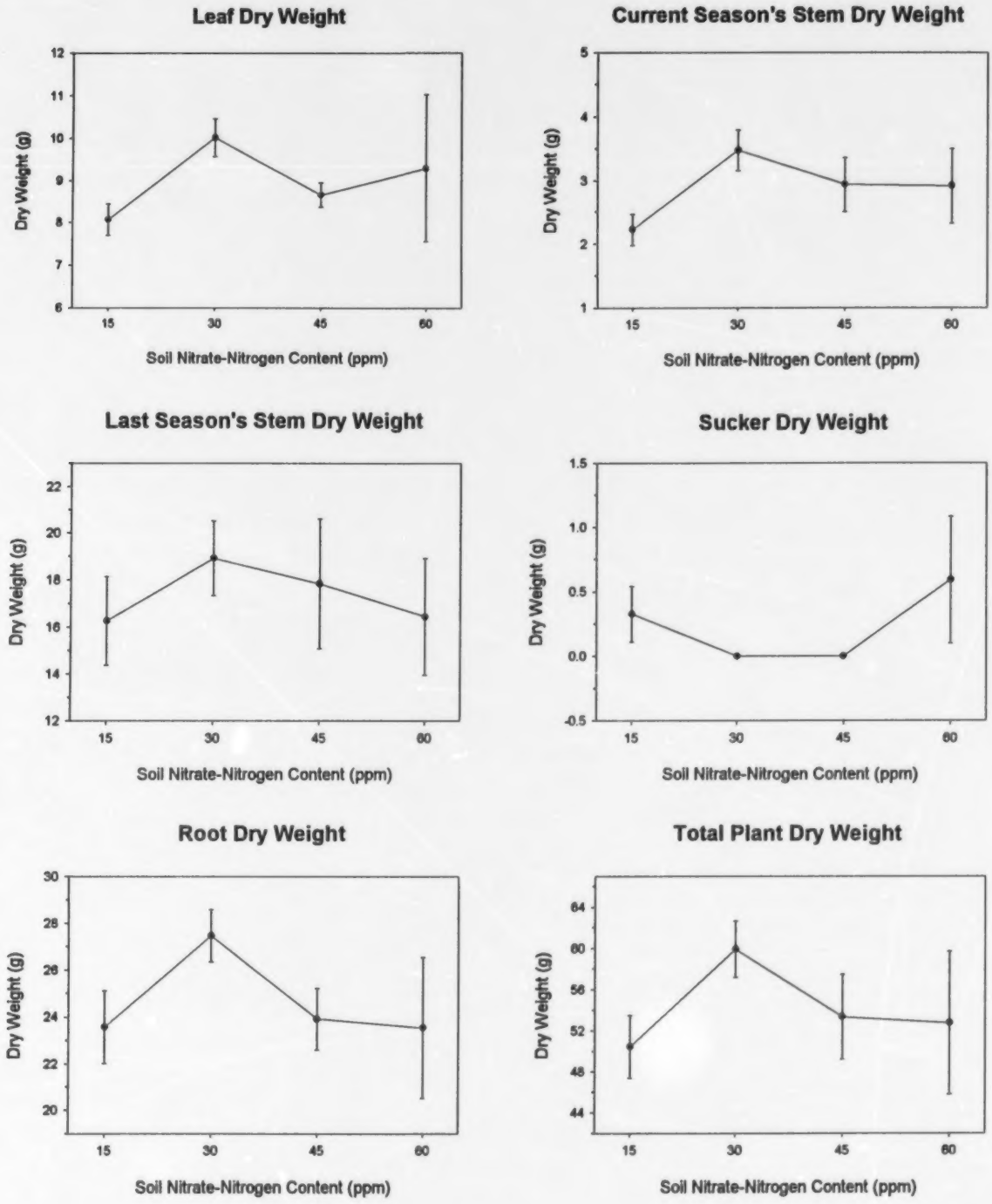
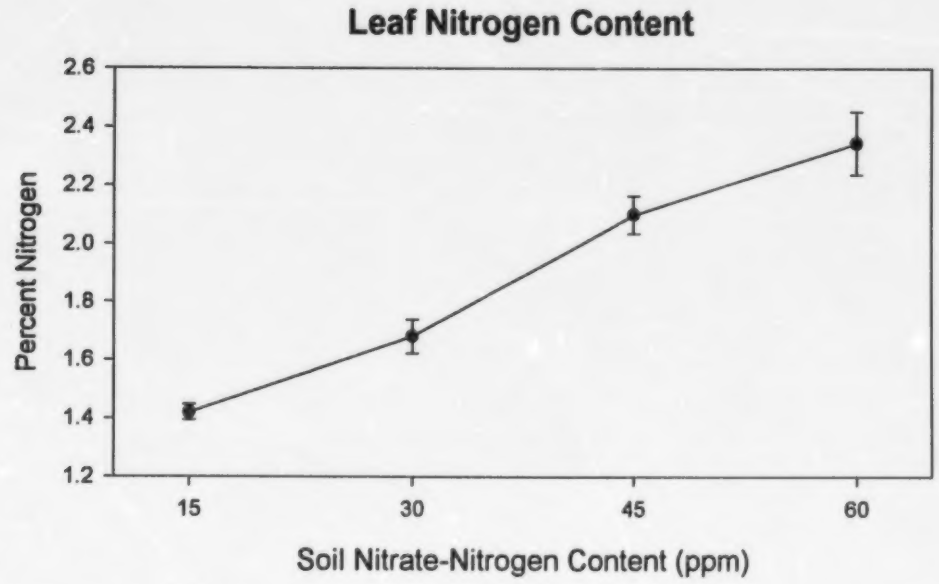


Figure 36. Growth response of potted saskatoon plants grown in the greenhouse in 1998 at four different soil nitrogen levels. Growth is expressed as percent dry weight of 3 plants.



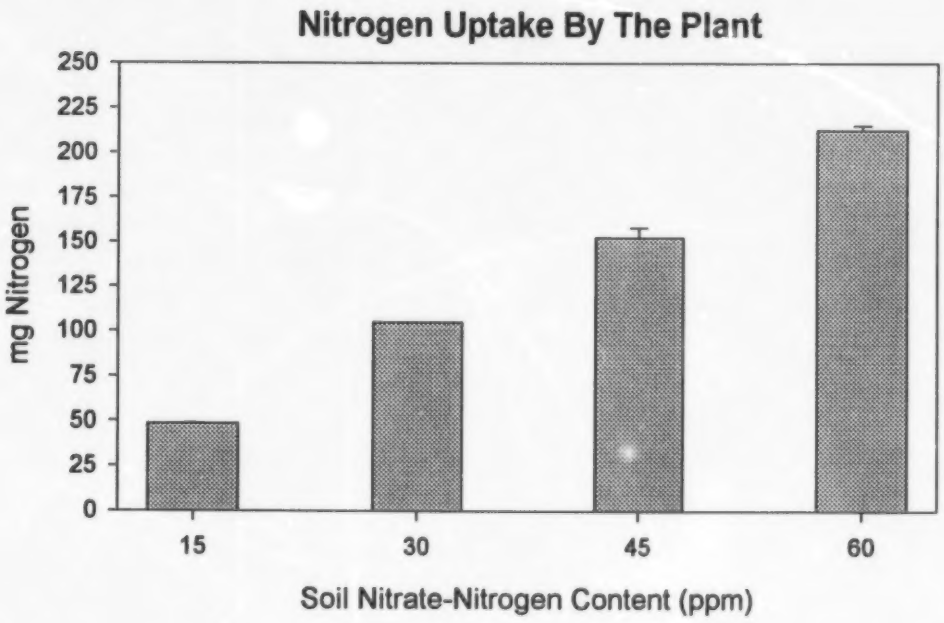


Figure 37. Leaf nitrogen content and nitrogen uptake of potted saskatoon plants grown in the greenhouse in 1999-00 at four different soil nitrogen levels.

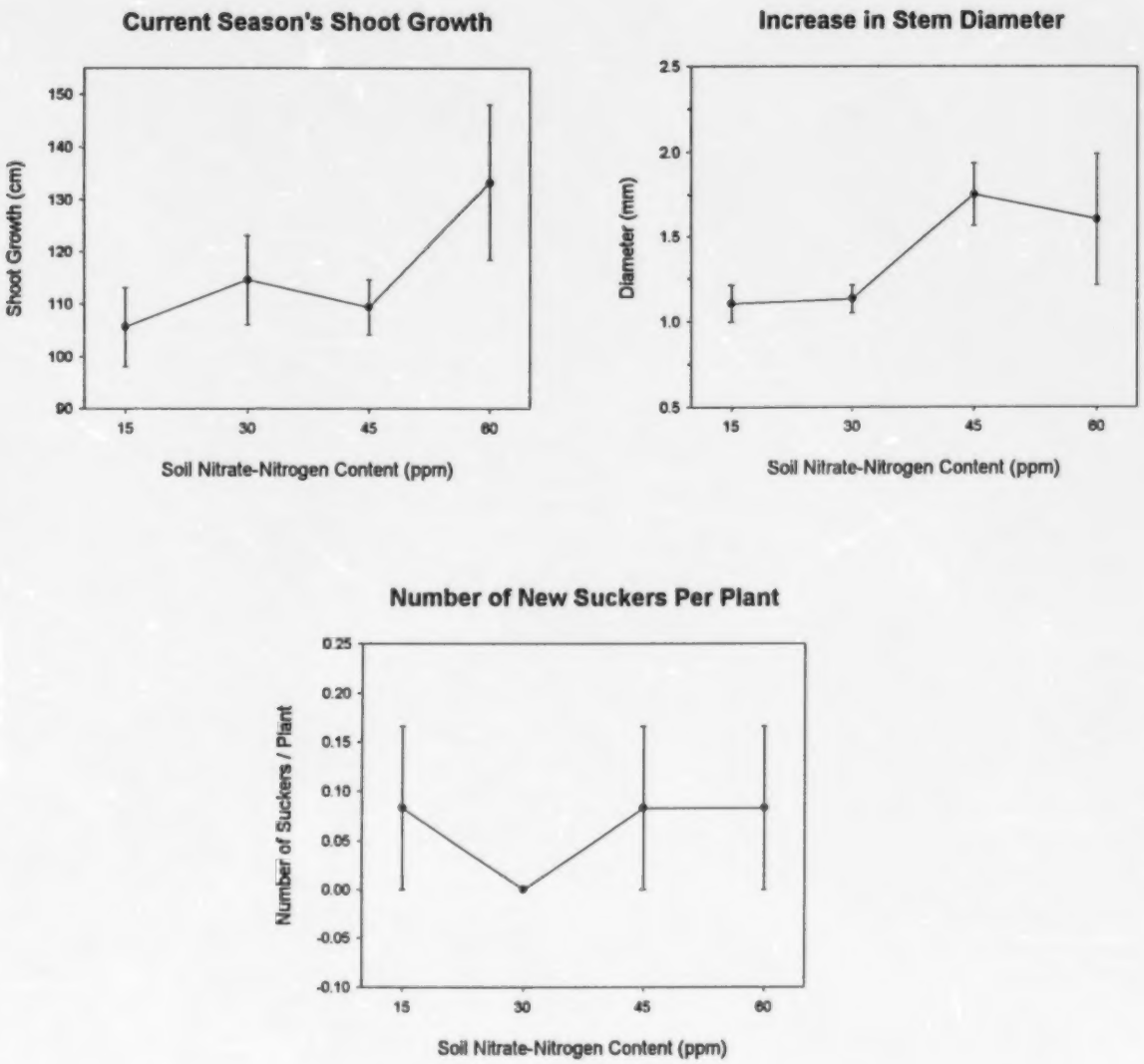


Figure 38. Growth response of potted saskatoon plants grown in the greenhouse in 1999 at four different soil nitrogen levels. Growth is expressed as an average of 3 plants.

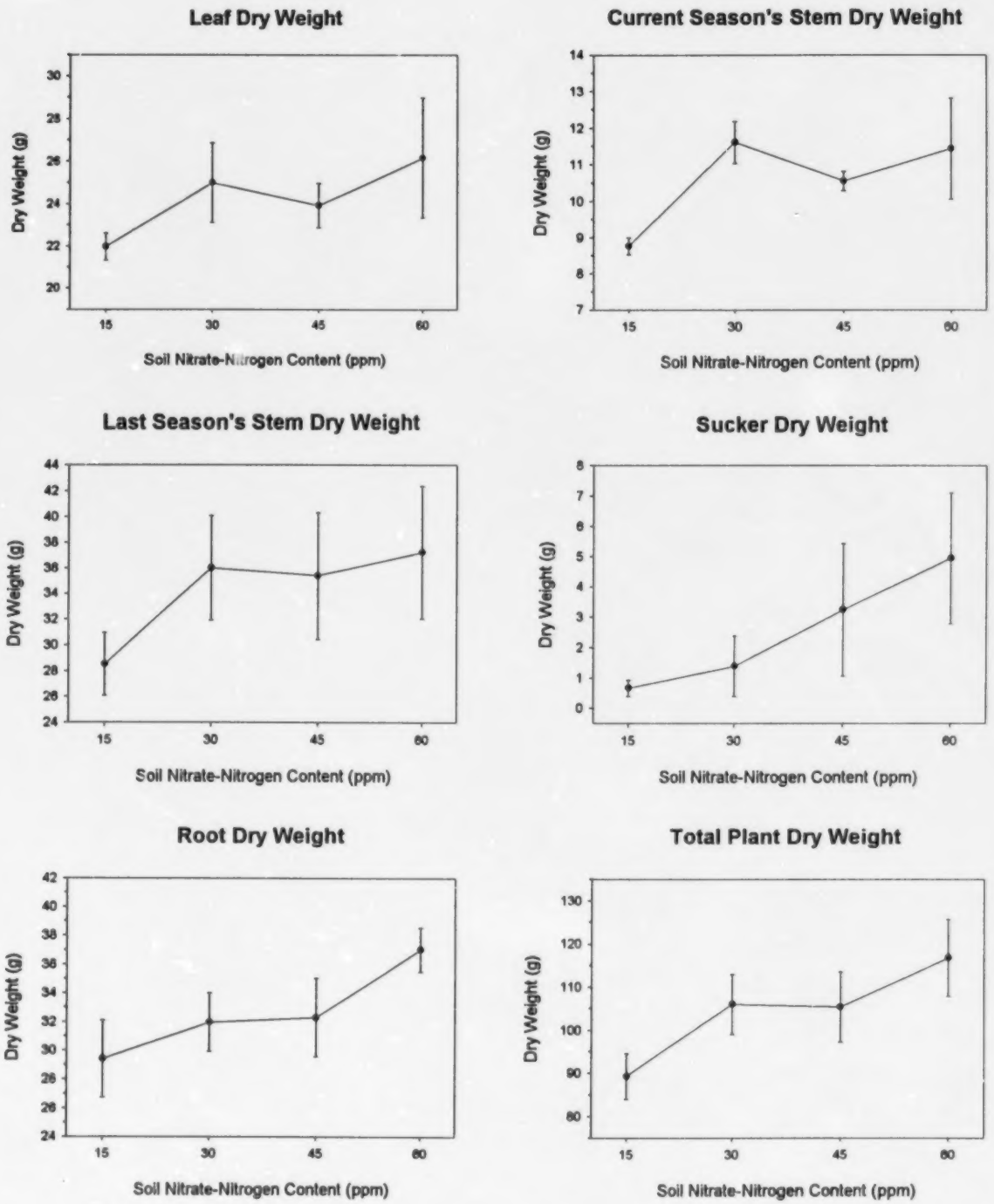


Figure 39. Growth response of potted saskatoon plants grown in the greenhouse in 1999 at four different soil nitrogen levels. Growth is expressed as percent dry weight of 3 plants.

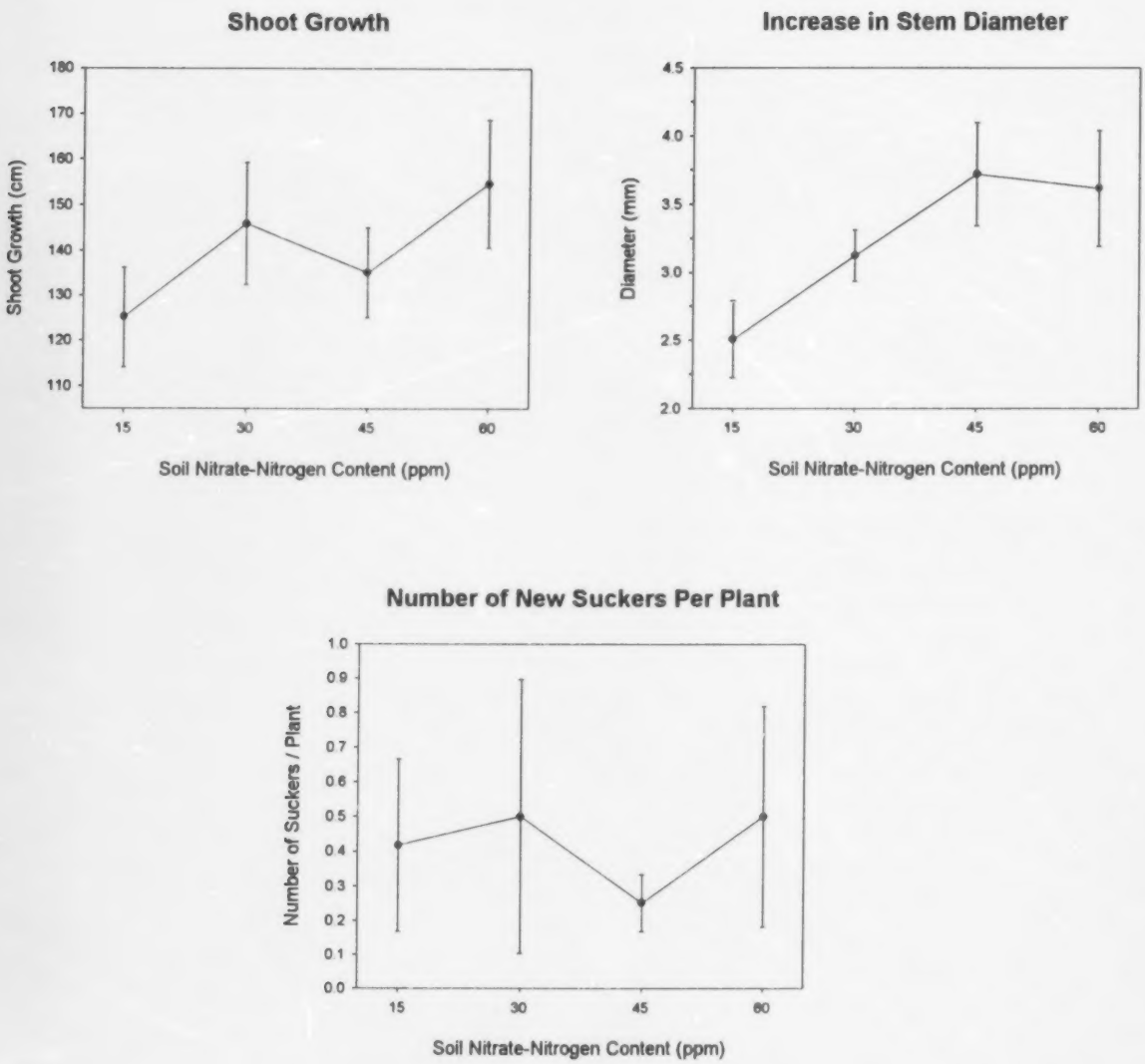


Figure 40. Growth response over two years of potted saskatoon plants grown in the greenhouse in 1998 and 1999 at four different soil nitrogen levels. Growth is expressed as an average of 6 plants.

(leaf: r=0.54; N uptake: r=0.54), total plant dry weight (leaf: r=0.52; N uptake: r=0.63), and increase in stem diameter over two years (leaf: r=0.52; N uptake: r=0.63). Plant nitrogen uptake was also correlated with the dry weight of the current season's stem growth (r=0.56). Soil nitrate levels at the end of the season were positively correlated with the increase in stem diameter in the second year (r=0.73) and over the two years (r=0.70).

Discussion and Conclusions

The effect of the nitrogen fertilizer treatments were stronger in the second growing season due to the accumulated effect of growing the plants at the same nitrogen regimes for two years. During the first growing season, the various nitrogen levels had little influence on growth. The number of new suckers differed according to treatment although not in a linear fashion. Stem diameter also increased significantly in a linear response with an increase in nitrogen, however, most of this increase occurred between the first and second treatment level. Plant growth showed a much greater response to treatments following the second growing season. In this case, stem diameter, shoot growth, and stem, root and total plant biomass increased with an increase in nitrogen. Stem diameter and shoot growth measured over two years also showed a significant linear response to nitrogen levels. Leaf nitrogen content was strongly affected in both years by soil nitrogen treatments. A strong positive linear relationship existed between leaf nitrogen content and soil nitrogen rates. Plant nitrogen uptake was also strongly correlated with leaf nitrogen content in both years.

Overall, nitrogen rates had little effect on growth during the first season likely because even the lowest level of nitrogen was probably adequate for sufficient growth. During the second season, the plants were larger but still contained in the same size pots creating a pot-induced fertilizer deficiency. Out in the field, the same size plants probably would spread out over a much greater volume of soil permitting access to a greater amount of nitrogen even though nitrogen concentration in the soil may be the same as in the pots. The nitrogen deficiency in the second season is readily apparent by the leaf nitrogen levels. During the first growing season, leaf nitrogen ranged from 2.08 to 2.85% which is the normal range at this stage of growth for saskatoons as indicated by foliar analysis (Table 14). However, during the second year, leaf nitrogen ranged from 1.42 to 2.35%. Only the two highest nitrogen treatments (2.10 and 2.35% N, respectively) had sufficient leaf nitrogen concentrations.

Based on growth response and leaf nitrogen content during the first year, the 30 ppm rate was likely adequate for optimum growth. At this rate, leaf nitrogen content was at 2.33% which was found to be just below average (Table 14). Plants at the 30 ppm treatment took up 108 mg of nitrogen. Average plant dry weight at this treatment was 20 g, resulting in 5.42 mg of nitrogen taken up by the plant per gram of plant dry weight. During the second growing season, the 60 ppm rate was necessary for adequate growth. Leaf nitrogen content was 2.35% at this rate which was also about average. Plants took up 213 mg of nitrogen at the 60 ppm rate. Average plant dry weight at this treatment was 39 g, thus, 5.46 mg of N/g of plant dry weight were required to yield this leaf nitrogen concentration.

Field Fertilizer Experiment - 1998 & 1999

A field fertilization experiment was established at a cooperative grower's site near White City. This site was selected for its light soil texture which is more inclined to have low soil nitrogen levels. It was hoped that this study would provide information on the effect of nitrogen fertilization on flowering and fruit set of saskatoons in a field situation.

This study consisted of four fertilizer rates (0, 25, 50, 75 lbs. nitrogen/acre) and three replicates. One row of Smoky saskatoons was selected for the experiment. This row was divided into 12 plots of seven plants each. Data and leaf samples were taken from only the inside five plants within a plot. Fertilizer treatments were applied on May 11, 1998 and May 15, 1999 in the form of urea (46-0-0). Leaf and soil samples were taken once a month from each plot. Soil samples were taken at two depths (0-9 in. and 9-18 in.) from four soil cores per plot. In 1998, on Sept. 6, soil was sampled only from the first depth because the soil was too dry at this time making sampling difficult from the lower depth. In 1999, the last set of soil and leaf samples were not taken at the end of the summer due to a high *Entomosporium* infestation. At the end of both seasons, the length of the current season's shoot growth was measured. Data on the number of flowers per branch and the number of branches per cluster were recorded in the spring of 1999. Data analysis was accomplished by analysis of variance, contrasts and Pearson correlations. Statistical analysis was done by each date separately and for all dates combined.

First Year Results

Soil and leaf nitrogen levels for the four sampling dates are presented in Figure 41.

May 24: Fertilizer treatment had a significant effect on nitrogen level in the first soil depth. Contrasts revealed a significant positive linear response of soil nitrogen content in the first soil depth to fertilizer treatment. The average soil nitrogen content at the two higher rates were significantly greater than that at the two lower rates. Soil nitrogen content was not significantly different in the lower depth on this date.

June 28: Contrasts indicated a significant linear response of soil nitrogen to fertilizer rate as averaged over both depths. As well, average nitrogen at both depths was significantly higher at the 75 lbs./acre rate than at the lower rates combined. On this date, leaf nitrogen content was correlated with soil nitrogen in the first depth ($r=0.66$) and with that averaged over both depths ($r=0.65$).

July 26: Contrasts indicated that soil nitrogen level as averaged over both depths and in the first depth was significantly higher in plots of treatment 75 than that of all other treatments combined. Soil nitrogen levels in the lower depth were significantly correlated with current season's shoot growth ($r=0.72$) on this date.

Sept. 6: Nothing was significant on this date.

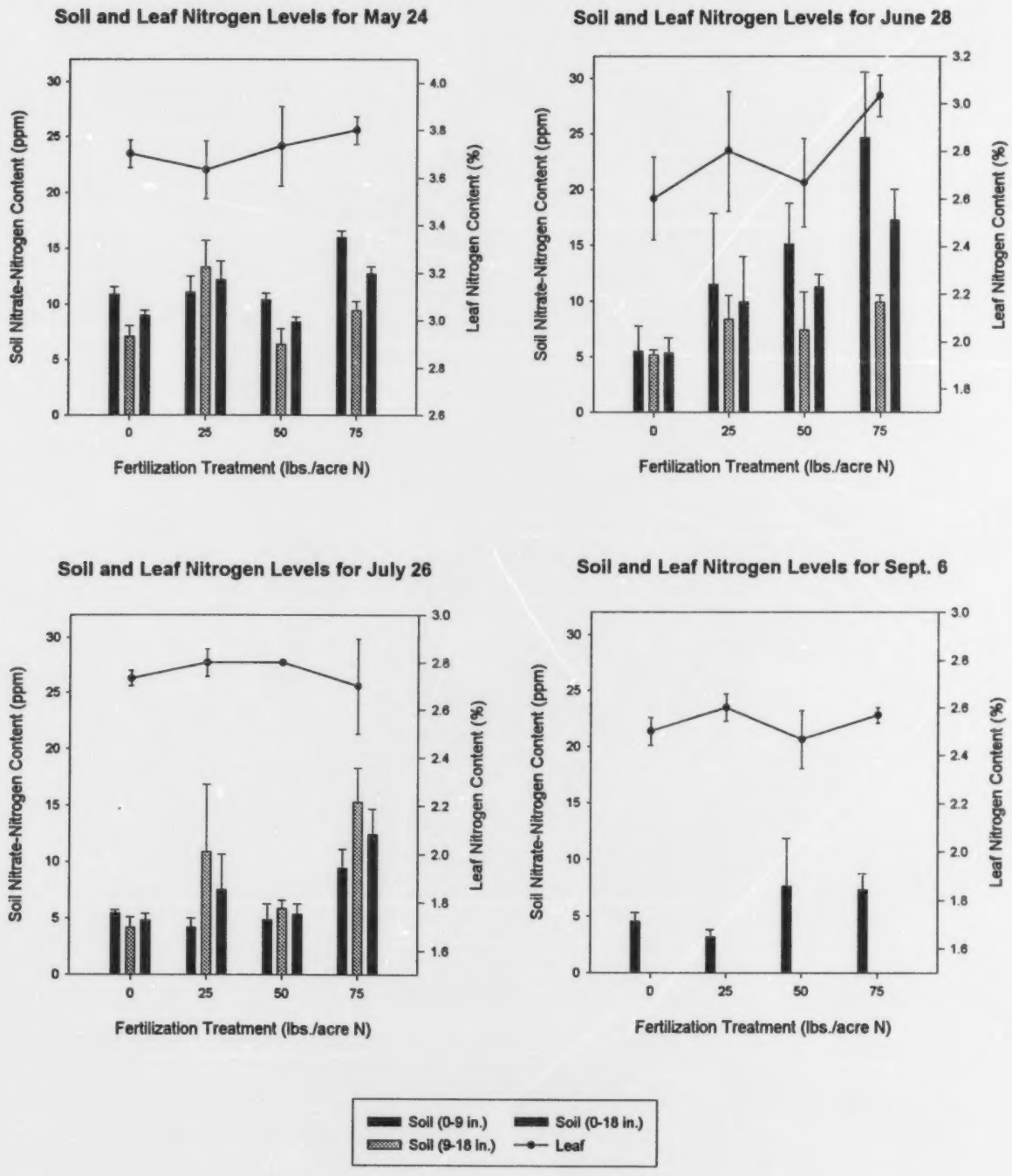


Figure 41. Soil and leaf nitrogen levels of saskatoon trees in the field as measured on four different dates following nitrogen fertilization in 1998.

All dates: Figure 42 shows the leaf and soil nitrogen levels averaged over all sampling dates. The measure of the current season's shoot growth is also presented. Contrasts indicated significant linear effects of treatment on soil nitrogen at the first soil depth and the two depths averaged together. The second depth showed significant cubic effects likely due to nitrogen levels at the 25 rate being higher than that at 50. The average nitrogen level of fertilized plots was significantly greater than in non-fertilized plots in soil at the lower depth and in the average of the two. Soil nitrogen level at the fertilizer rate of 75 was significantly higher than that of the lower rates combined in both the first depth and the average of the two.

Leaf nitrogen and that in the soil at both depths averaged together were also correlated significantly (r=0.64). Current season's shoot growth was correlated with soil nitrogen levels in the second depth (r=0.73).

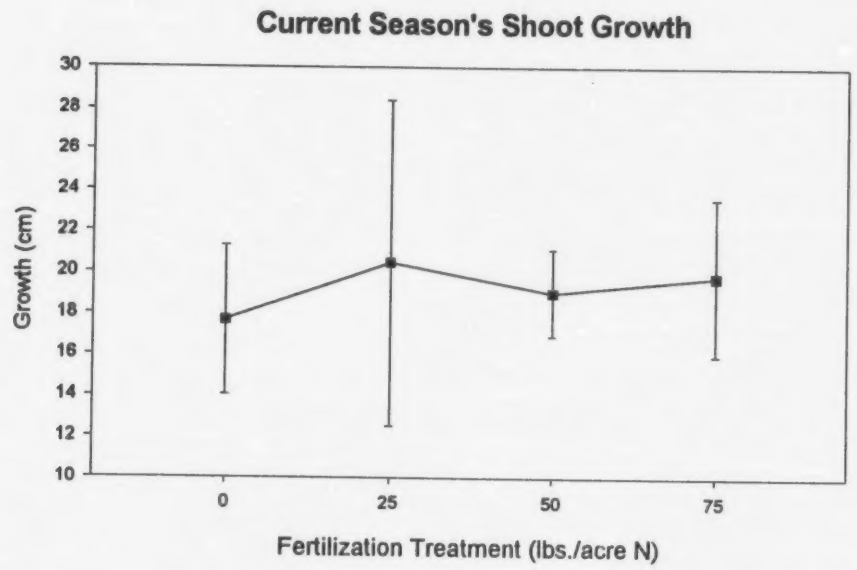
The number of flower clusters per branch, the number of flowers per cluster, and the total number of flowers per branch did not differ significantly in response to nitrogen fertilizer treatments, nor were they correlated with leaf nitrogen or soil nitrate levels on any of the sampling dates (Figure 43).

Discussion and Conclusions - 1998

In general, most of the effect of nitrogen fertilization occurred in the first soil depth. There were no linear or treatment effects of nitrogen in the second soil depth alone. On June 28 the nitrogen content of the two soil depths together showed more significant linear and treatment effects than that in the first depth alone (Table 21). This suggests that perhaps some nitrogen from the fertilizer treatments had leached down into the lower depth by this date. However, once again by July 26 most of the fertilizer effect remained in the first depth. Some of this variability is likely due to sampling. The linear and treatment contrasts were more significant when all dates were averaged together as well, also indicating that some of the nitrogen from the fertilizer application had leached down into the second depth. The effect of nitrogen fertilization appeared to be completely gone by Sept. 6.

Table 21. Probability values for contrasts of treatment effects for the field fertilizer study in 1998.

Date	0-9 inch soil depth		0-18 inch soil depth	
	Linear Effects	0 to 50 vs. 75	Linear Effects	0 to 50 vs. 75
May 24	0.0145	0.0034	0.1649	0.0553
June 28	0.0507	0.0745	0.0274	0.0437
July 26	0.0482	0.0149	0.0772	0.0403
Sept. 6	0.252	0.4335	N/A	N/A



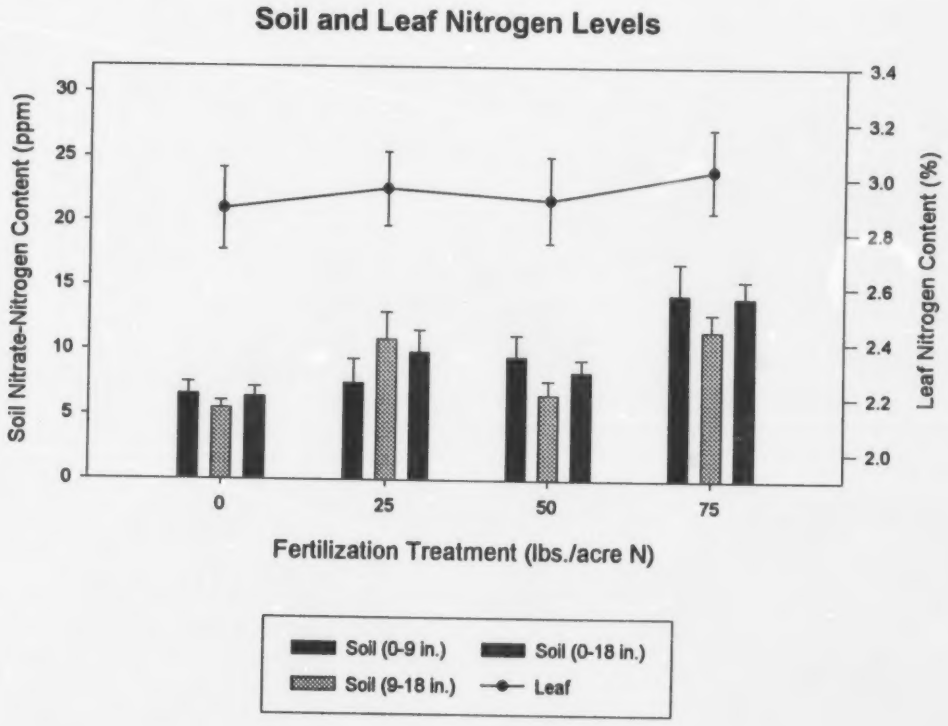
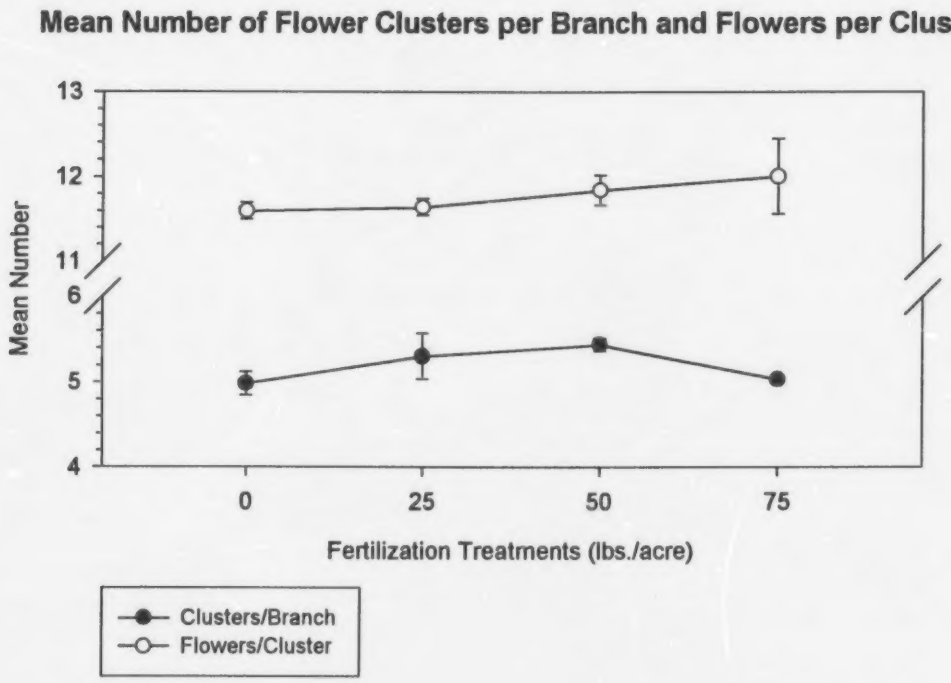


Figure 42. Current season's shoot growth, and soil and leaf nitrogen levels of saskatoon trees in the field following nitrogen fertilization treatments. Nutrient levels are averages from samples taken once a month from May until August in 1998.



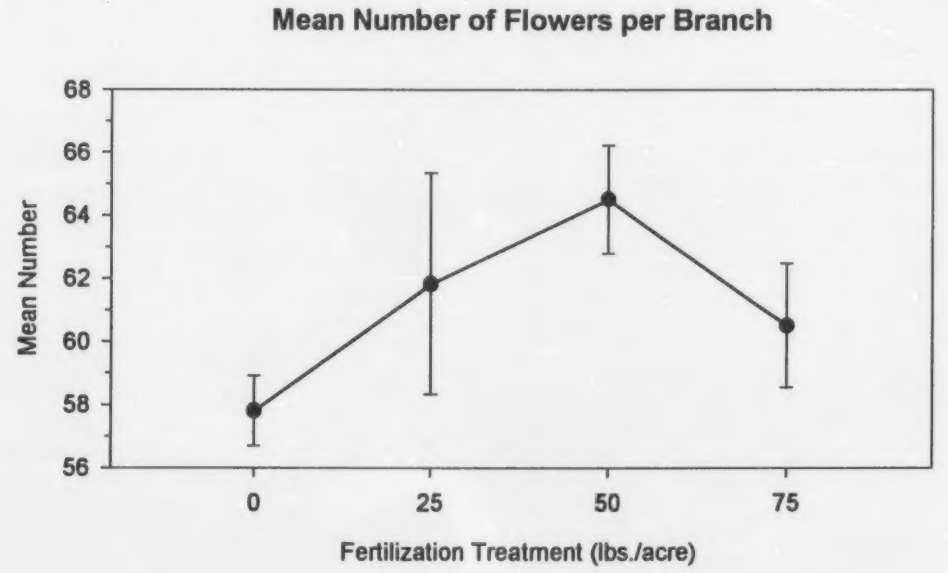


Figure 43. The number of flowers per cluster, clusters per branch and total number of flowers per branch of saskatoon trees in 1999 in the field following nitrogen fertilization in the previous spring.

All dates	0.0293	0.03	0.0082	0.0063

Leaf nitrogen level was correlated with that in the soil only on June 28 and when all dates were averaged together. Growth was only correlated with soil nitrogen levels in the second depth on July 26 and when all dates were averaged together. Growth overall was not found to be significantly different. One reason for this may be that the nitrogen fertilizer treatments did not create large enough nitrogen gradients in the soil to be reflected in the plant in terms of growth. As well, the growth of perennial plants are strongly influenced by plant nutrient stores from previous years. Continual nitrogen fertilization at different rates for a number of seasons would create a stronger soil nitrogen gradient which may become apparent in the tree's nitrogen content and growth.

Second year results

Soil and leaf nitrogen levels for the three sampling dates in 1999 are presented in Figure 44.

June 5: Contrasts indicated a significant linear response to fertilizer rate of soil nitrate levels at both depths and in the average of the two. Leaf nitrogen content in June was significantly correlated with soil nitrate levels in the first depth (r=0.67) and with the average of the two depths (r=0.67). Current season's shoot growth was correlated with leaf nitrogen levels (r=0.62), soil nitrate in the first depth (r=0.79), and in the average of the two depths (r=0.78).

July 3: Soil nitrate in the first depth increased linearly in response to fertilizer rate in July.

August 7: Soil nitrate levels in the two depths and both averaged together had a significant linear increase in response to an increase in fertilizer rate. Current season's shoot growth was positively correlated with soil nitrate levels in the second depth (r=0.66).

All dates: Contrasts indicated a significant linear response to fertilizer treatment of soil nitrate levels as averaged over the three sample dates at both depths and the two averaged together (Figure 45). Current season's shoot growth was positively correlated with mean soil nitrate level at the two depths averaged together (r=0.64).

Discussion and Conclusions, 1999

In general, the fertilizer treatments had a greater effect in the second year than the first season. This is likely due to the accumulated effect of the fertilizer treatments over the two years. A greater number of significant contrasts for linear effects and trend analysis occurred in the second season (Table 22) than the first (Table 21). In fact soil nitrate levels in the first depth and for the two averaged together were significant for all linear contrasts and trends on all dates except in July for the 0-18 in. depth. Linear effects were also found to be significant for soil

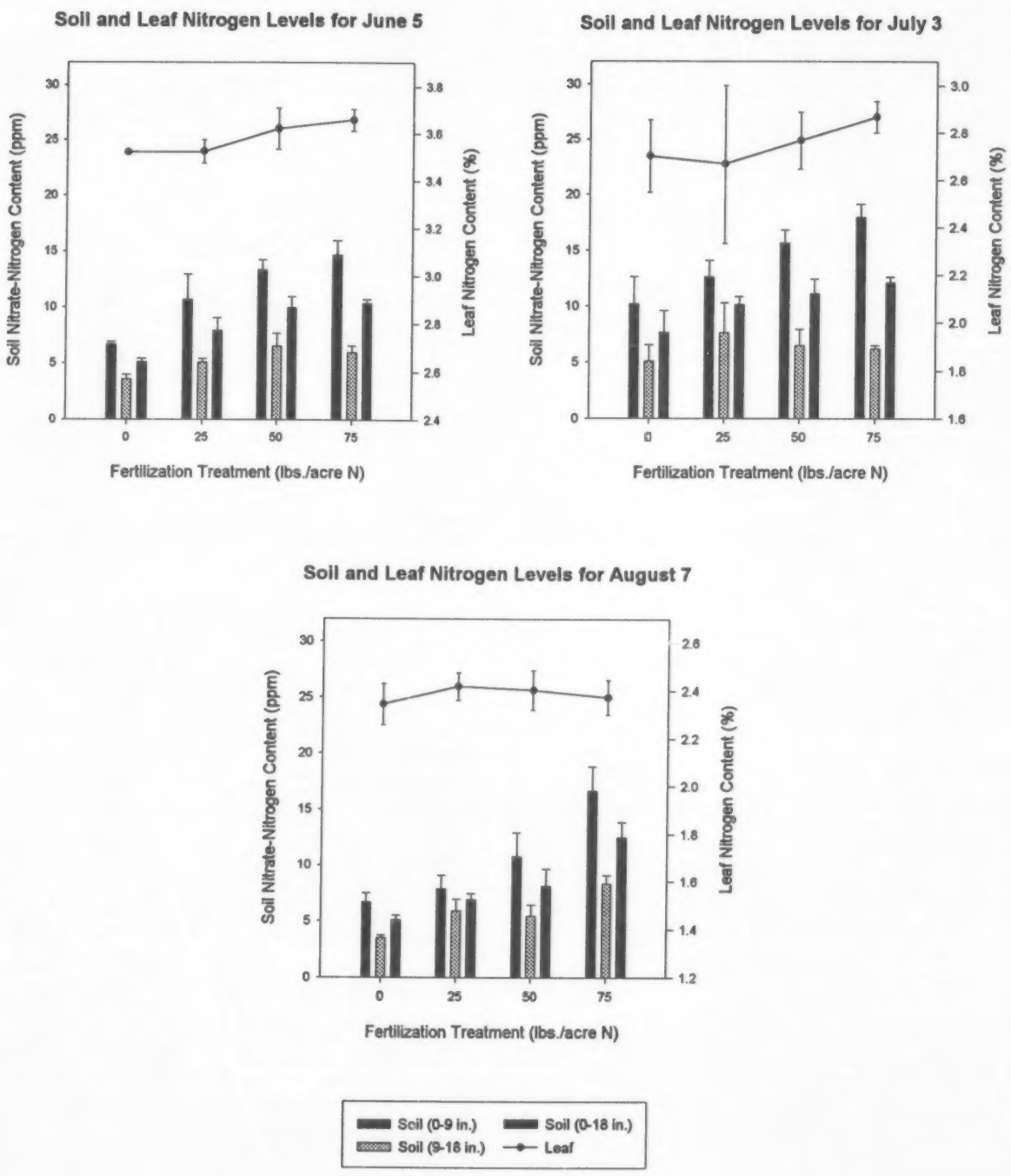
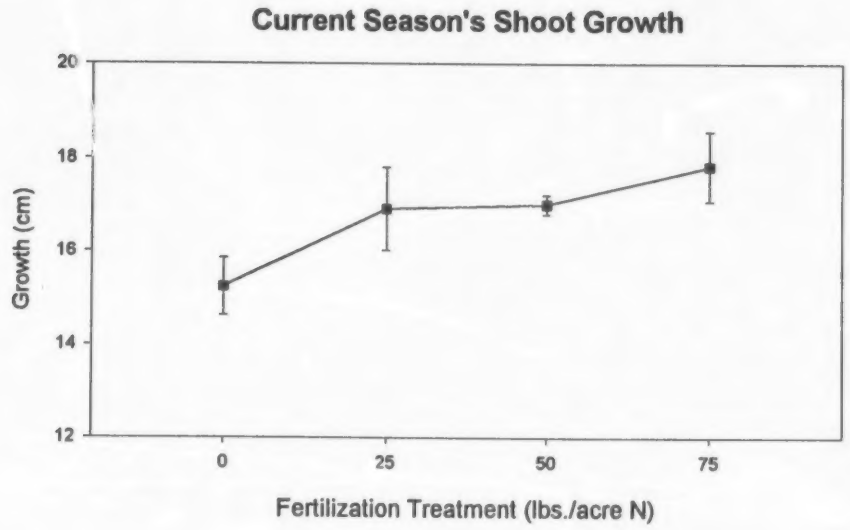

Soil and Leaf Nitrogen Levels for June 5
Soil Nitrate-Nitrogen Content (ppm)
Leaf Nitrogen Content (%)
Fertilization Treatment (lbs./acre N)
Soil and Leaf Nitrogen Levels for July 3
Soil Nitrate-Nitrogen Content (ppm)
Leaf Nitrogen Content (%)
Fertilization Treatment (lbs./acre N)
Soil and Leaf Nitrogen Levels for August 7
Soil Nitrate-Nitrogen Content (ppm)
Leaf Nitrogen Content (%)
Fertilization Treatment (lbs./acre N)
Soil (0-9 in.)
Soil (0-18 in.)
Soil (9-18 in.)
Leaf

Figure 44. Soil and leaf nitrogen levels of saskatoon trees in the field as measured on three different dates following nitrogen fertilization in 1999.



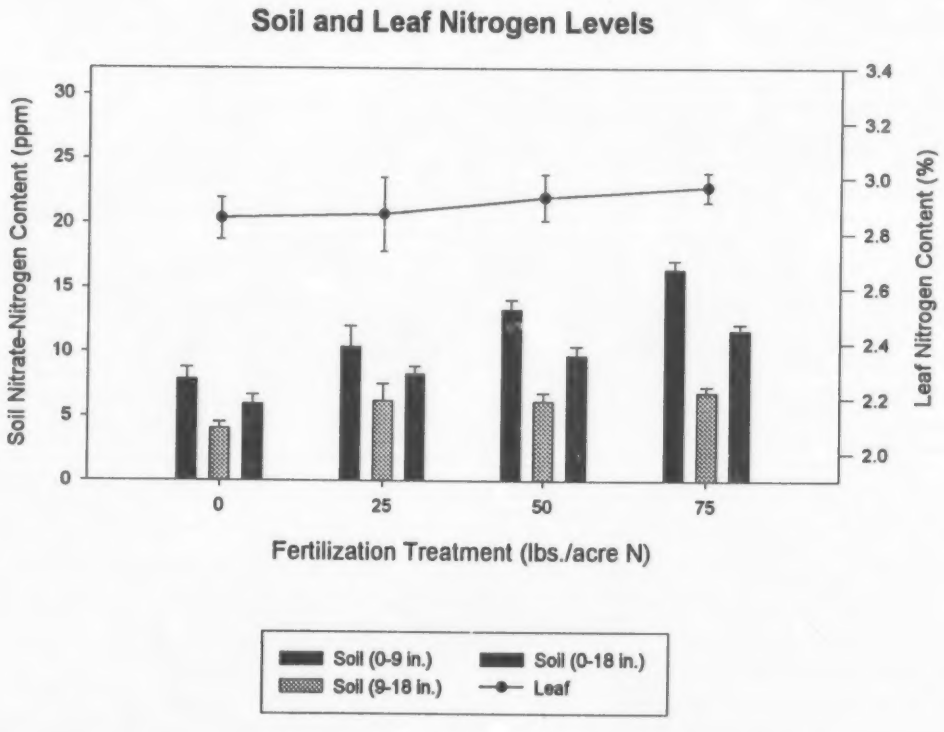


Figure 45. Current season's shoot growth, and soil and leaf nitrogen levels of saskatoon trees in the field following nitrogen fertilization treatments. Nutrient levels are averages from samples taken once a month from June until August in 1999.

nitrate in the lower depth in June, August, and for all the dates averaged together. A linear relationship of soil nitrate was not found in the second depth the year before. The nitrate fertilizer may have required time to permeate through the soil and influence nitrate levels in the second soil depth, but, nitrate levels in the second depth during the first season were higher than in the second season. The accumulated effect of two years of fertilization may in part explain this trend occurring in the second year but not the first. However, as in the year before, the majority of the effect of nitrogen fertilization occurred in the first depth.

Table 22. Probability values for contrasts of treatment effects for the field fertilizer study in 1999.

Date	0-9 inch soil depth		0-18 inch soil depth	
	Linear Effects	0 to 50 vs. 75	Linear Effects	0 to 50 vs. 75
June 5	0.0052	0.0329	0.0038	0.0364
July 3	0.0125	0.0372	0.0555	0.1613
Aug. 7	0.0012	0.0015	0.0016	0.002
All dates	0.0006	0.0019	0.0005	0.0021

As in the first season, leaf nitrogen was correlated with soil nitrate levels only in June, indicating perhaps either a greater uptake of nitrogen by the plants at this time of the year, or soon after fertilizing. Shoot growth also responded more to fertilization treatments in the second season than in the first. In the second year, current season's shoot growth had a linear response to treatment and was correlated to leaf nitrogen in June, and soil nitrate levels in June and August.

Leaf nitrogen content was greater in the first season than in the second. It is not known why leaf nitrogen was higher than average in the first season as soil nitrogen levels was approximately the same in both years, with the exception of soil nitrate being greater in the second depth in 1998 than in 1999. If the trees acquired a greater amount of soil nutrients from the second soil depth than the first, than this may explain this occurrence, however one would expect a greater number of correlations to have occurred between leaf nitrogen and soil nitrogen in the second soil depth if this were the case. Leaf nitrogen levels in 1998 may also have been influenced by previous fertilization practices and stored nutrients within the plant.

Overall, the plants did respond to nitrogen fertilization. Nitrogen increased shoot growth which would be expected as nitrogen promotes vegetative growth. However, the ideal fertilization rate for nitrogen would not only depend on its influence on growth but on flowering as well. Although data on flowering was not significant, the total number of flowers did tend to increase until the 50 lbs./acre rate and then decreased at the highest nitrogen rate. The decrease at the highest rate may have occurred because nitrogen in excess promotes vegetative growth at the

cost of reproductive growth. In this case, it may be that nitrogen beyond the rate of 50 lbs./acre will decrease flowering and thus yield. However, more data is required to determine if this trend will continue. Flowering data will be collected in the spring of 2000. Following fertilization over a number of seasons, the effect of nitrogen rate on flowering may become more apparent.

General Conclusions of the Fertilization Study

The fertilization component of this project involved the analysis of soil and leaf tissue samples along with a number of greenhouse and field experiments. To develop standards for foliar nutrient levels in saskatoons and chokecherries, leaf samples were collected from saskatoons in 15 orchards, and from chokecherries in 3 sites. Typical leaf levels for the saskatoon in the month of August were nitrogen - 2.3 to 2.6%, phosphorus - 0.13 to 0.19% and potassium - 0.71 to 1.1%. Typical leaf levels for the chokecherry were nitrogen - 2.3 to 3%, phosphorus - 0.14 to 0.26% and potassium - 0.58 to 1.5%. A relationship between leaf and soil nutrients was not found in the field. This was likely due to the large variability in the data. This has been the most comprehensive study to date on the foliar analysis of saskatoons and chokecherries. Foliar analysis is particularly useful in determining the nutrient status of deep-rooted crops where soil sampling to the depth of tree roots can be difficult. Foliar nutrient standards allows growers to monitor leaf nutrient levels in their orchard and to fertilize accordingly to maintain these levels at typical concentrations.

Additional greenhouse pot and field experiments were initiated in order to derive additional information on plant response to the addition of varying levels of nitrogen. The field nitrogen fertilization project permitted the examination of leaf and soil nutrients under less variable conditions involving only one cultivar and one site. In this study, a relationship among soil and leaf nitrogen and shoot growth was found. The fertilization experiments of potted saskatoon plants grown in the greenhouse were valuable in establishing relationships between soil nutrient content, plant nutrient uptake, leaf nitrogen content, and plant growth response. The greenhouse research permitted nutrient uptake by the plant to be monitored. The plant nitrogen uptake of the greenhouse fertilization experiments is summarized in Table 23.

Table 23. Summary of the results of the greenhouse fertilization experiments of potted saskatoon plants.

	20-20-20/1998	20-20-20/1999	N Exp./1st yr.	N Exp./2nd yr.
Season of growth	2nd	2nd	3rd	4th
Plant Height (cm)	76	34	49	67
Plant Dry Weight (g)	32.4	13.1	20	38.9
Nitrogen Uptake (mg)	192.4	65.9	108.4	212.5
mg N uptake / g Dry Wt.	5.9	5.1	5.4	5.5

Leaf Nitrogen Content (%)	2.68	2.39	2.32	2.35
Correlation Coefficient for leaf N & N uptake	0.85	0.85	0.92	0.94

Based on these studies, the average amount of nitrogen taken up by the saskatoon plants to ensure an adequate leaf nitrogen content (mean = 2.4%) was 5.5 mg N/g plant dry weight. The relationship between nitrogen uptake by the plant and its leaf nitrogen content was quite strong with an average correlation coefficient of 0.89; in other words, 89% of the plant's leaf nitrogen content was dependent on the amount of nitrogen taken up by the plant. From the results of the greenhouse experiments, one can estimate that the average one-year old saskatoon plant in the field would require approximately 100 mg of nitrogen from the soil. However, obviously more than this amount nitrogen fertilizer needs to be added to the plant root zone as the plant's roots will not be able to take up all of the nitrogen from the soil but only what its roots come in contact with.

On the basis of the work done in the fertilizer study, it appears that 25 to 45 lbs/acre of nitrogen could be applied to saskatoon orchards annually. However, the preferred method of adding fertilizer should be a proportional application based on soil nutrient loss and decrease in leaf tissue levels, provided that minimal initial levels of soil nutrients were in place when an orchard was established. Although typical leaf nutrient concentrations were determined in this study, additional research would be useful in order to refine this data in terms of nutrient deficiencies and toxicities. A larger scale study could also examine foliar nutrient content of plants of different cultivars or grown in the various soil zones. The quantity of fertilizer that needs to be applied in the field can only be determined through a number of seasons of field fertilization research. Fertilization research of plants grown in large pots to allow a natural root spread may also be beneficial. More research needs to be done on the effect of nitrogen fertilization on flowering of saskatoons and chokecherries. Some of the results of the soil and foliar analysis project were presented to growers at a Saskatchewan Fruit Growers workshop on February 25, 2000. Great interest was shown on the part of the growers in the use of foliar analysis to monitor the nutrient status and to determine the fertilization requirements of saskatoons and chokecherries. The growers felt that the results of this project were a good start, but expressed interest in seeing more research being done in this area.

4) Indications For Further Development

The results of this project suggest that longer term studies of fertilization and irrigation need to be carried out in order to obtain information useful in mature orchards.

5) Information Sharing

Publications

Zatylny, A. and R.G. St-Pierre. 1999. Typical nutrient levels of saskatoon and chokecherry leaves. The Prairie Fruit Journal 6(2): 3-4 (Spring 1999).

Zatylny, A. and R.G. St-Pierre. 1998. Soil and foliar analysis project. The Prairie Fruit Journal 5(2): 4-5 (Spring 1998).

Zatylny, A. and R.G. St-Pierre. 1998. Soil and foliar analysis - A Canada-Saskatchewan Agri-Food Innovation Fund Project. The Prairie Fruit Journal 5(1): 3-4 (Winter 97/98).

St-Pierre, R.G. 1996. Using soil moisture sensors to schedule irrigation. Department of Horticulture Science, University of Saskatchewan, Saskatoon, SK. 4 pp.

St-Pierre, R.G. 1996. Fertilizing saskatoons. Department of Horticulture Science, University of Saskatchewan, Saskatoon, SK. 10 pp.

Reports

St-Pierre, R.G. 1999. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Progress Report - October 15 for the Canada-Saskatchewan Agri-Food Innovation Fund.

St-Pierre, R.G. 1999. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Summary Report - July 31 for the Canada-Saskatchewan Agri-Food Innovation Fund.

St-Pierre, R.G. 1999. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Progress Report - April 15 for the Canada-Saskatchewan Agri-Food Innovation Fund.

St-Pierre, R.G. 1999. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Saskatchewan Irrigation Development Centre 1998/99 Annual Report; pp 154-155. March.

St-Pierre, R.G. 1998. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Progress Report - October 15 for the Canada-Saskatchewan Agri-Food Innovation Fund.

St-Pierre, R.G. 1998. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Progress Report - April 15 for the Canada-Saskatchewan Agri-Food Innovation Fund.

St-Pierre, R.G. 1998. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Saskatchewan Irrigation Development Centre 1997/98 Annual Report. March.

St-Pierre, R.G. 1997. Development of irrigation and fertilization guidelines to enhance saskatoon and chokecherry production and fruit quality. Progress Report - October 15 for the Canada-Saskatchewan Agri-Food Innovation Fund.

Presentations

St-Pierre, R.G. 1999. Fertilization and irrigation requirements of saskatoons. Fruit Growers' Society of Alberta Saskatoon and Chokecherry Production Workshop. Edmonton, AB; March 19-20.

St-Pierre, R.G. 1999. Fertility and irrigation requirements of saskatoons. Manitoba Horticultural Production Days. Brandon, MB; February 4-5.

St-Pierre, R.G. 1998. Nutrient and irrigation requirements of saskatoons. Saskatoon Berry Production Workshop. Saskatoon, SK; November 20-21.

St-Pierre, R. G. 1997. Saskatoon and chokecherry irrigation trials - research update. SaskHort '97 Convention and Trade Show. November 9-11, Saskatoon, SK.

St-Pierre, R. G. 1997. Soil and foliar analyses of saskatoons and chokecherries - research update. SaskHort '97 Convention and Trade Show. November 9-11, Saskatoon, SK.

6) Success & Relationship to Objectives

In large part, the objectives of this study were met, although this required substantial additional work not included in the original proposal and which was subsidized by funding from other sources.

7) Outputs & Deliverables

Project outputs have included: a) 5 publications, 8 reports, and 5 presentations; b) general guidelines for the irrigation of saskatoons and chokecherries using soil moisture sensors; c) the determination of typical leaf nutrient concentrations in saskatoons and chokecherries; d) general guidelines for the fertilization of saskatoons and chokecherries; and e) a statement of interest in the results of this project from members of the Saskatchewan Fruit Growers Association, and an expression of desire to see more work done in this area.

C) Personnel

R. St-Pierre - 5%
H. Tulloch - 10%
A. Zatylny - 30%
J. Hall - 20%
H. Driesdale- 20%
L. Pilsner - 20%

D) Equipment

None

E) Project Photos

Inserted in text where available.

F) Innovation Fund Acknowledgement

Refer to section on Information Sharing (above).

G) Copies of Information Developed

None to date.

H) Expense Statement

Sent under separate cover by Research Accounts, University of Saskatchewan.